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QUANTIFICATION OF BODY WEIGHT AND CONFIGURATION FROM ANTHROPOMETRIC MEASUREMENTS *

BY ALBERT R. BEHNKE
U. S. Naval Radiological Defense Laboratory
San Francisco 24, California

OTTO E. GUTTENTAG
School of Medicine
University of California Medical Center
San Francisco, California

and

CARROLL BRODSKY

INTRODUCTION

ONE of the most difficult measurements to make in all biology, namely, the surface area of the human body, can be calculated accurately from the parameters of height (h) and weight (W), and the

* A related article, The estimation of lean body weight from "skeletal" measurements, by Albert R. Behnke, is scheduled for publication in the December issue of *Human Biology*—Ed.

conversion constant K. The general form of the equation employed is $A = W^a \times h^b \times K$. Although this type of formulation appears to be universally applicable, the values for K and exponents a and b were obtained from measurements on less than 12 individuals. This fact indicates that in healthy adults whose body form is not distorted by excessive fat, there is an organized body structure or pattern characterized by anthropometric relationships obtainable on a few individuals and applicable to many.

In turn, body weight can be calculated with remarkable accuracy, as the data in this report will show, from the product of stature (h), a constant (K), and the squared sum of certain girth measurements and bideltoid diameter. It is possible also to divide the dimensions by a constant (k) to compute a "body radius," (R). If we employ a cylinder as a geometrical analogue of the body, then with units expressed in kilograms or decimeters,

$$W = \pi R^2 h \qquad \text{and} \qquad R = \sqrt{\frac{W}{\pi h}}$$

An additional constant (π) is introduced by the use of these formulas, but they serve to emphasize some interesting geometrical relationships, as von Schelling (1954) indicated, between body dimensions and surface area, as well as weight.

Essential and extensive supporting data for this analysis have been derived from several sources. Willoughby (1932) recorded certain envelope dimensions on a group of athletes, and also on young women, from which he computed optimal proportions of the body. The Air Force has prepared exemplary brochures summarizing data on 4,000 men (Hertzberg, *et al.*, 1954), and on young women (Daniels, Meyers, Worrall, 1953) and men trainees (Daniels, *et al.*, 1953). Earlier measurements on 25,000 Army separatees, and those of Randall *et al.* (1949) are especially valuable for the purposes of this analysis. These military investigations were broad anthropometric surveys, but the mean and percentile distribution of values recorded for the different groups are in good agreement. The techniques employed (invariably with a few exceptions) also are the same. It was possible, therefore, from the Navy sample to derive constants for the conversion of anthropometric dimensions into equivalent weights which were nearly identical to those we have derived from an analysis of data on much larger groups.

BASIC RELATIONSHIPS

The mean and median values for the anthropometric dimensions are nearly the same. In random samples, the coefficients of variation (C. V.) of a number of measurements, if stature and waist girth are excluded,

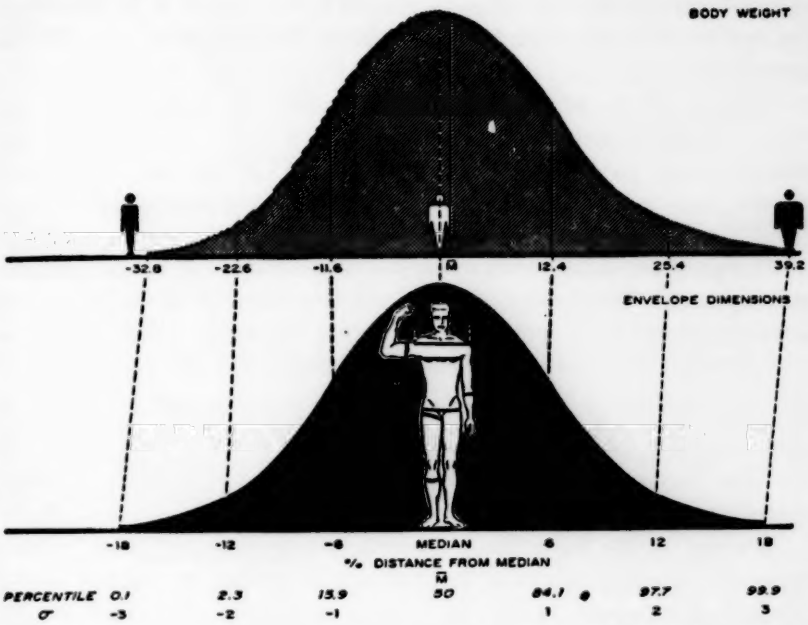

FIG. 1. Distribution of body weights (upper curve) in relation to the squared values of anthropometric dimensions (lower curve) for a given stature. The relationship between correlates in the upper and lower curves is indicated by the connecting lines. If the sum of an individual's dimensional values lies at a distance of 6% to the right of the median dimensional value (lower curve), his body weight value will lie at a distance of 12.4% to the right of the median weight value (upper curve).

fall in the range of 5 to 8. For example, from the data of Hertzberg *et al.* (1954), the C. V. for the bideltoid diameter is 5.1, and for the girths of the shoulder, 5.5; chest, 6.3; biceps, 8.3; forearm, 6.4; buttocks, 6.1; thigh, 7.8; and calf, 6.7. If an average rounded value of 6% is used, then with stature constant, the distribution of anthropometric dimensions is depicted by the lower curve in figure 1.

The C. V. for body weights is about twice that computed for the anthropometric dimensions, *e. g.*, from the data of Hertzberg *et al.*, C. V.

(Weight) = 12.74%. The distribution of body weights calculated from the squared values of the anthropometric dimensions is shown in the upper curve of figure 1. Thus, if an individual's position on the dimensional distribution curve is 6% to the right or 6% to the left of the median value (M), as the case may be, his position on the weight distribution curve will be 12.36% to the right or —11.46% to the left of the median value for body weights, respectively. This follows from the formulas,

$$(M + .06M)^2 = M^2 + .1236M^2$$

and

$$(M - .06M)^2 = M^2 - .1164M^2.$$

Intrinsic meaning of the coefficients of variation.

With respect to the relationship of variables such as weight (Y) and anthropometric dimensions (X) amenable to expression by the logarithmic formulation,

$$\log Y = \log bX + \log a,$$

the value for the slope b (provided X and Y are highly correlated), is aproximated by the ratio of C. V. (Y) to C. V. (X), Behnke (1953). For the purpose of our analysis, this ratio is not critically different from two.

Stature in the logarithmic formulation is incorporated in log (a). Thus, the logarithmic plot of the relationship between weight and anthropometric dimensions consists of a series of parallel lines each of slope log b, and separated from each other by the distance determined by the values of stature incorporated in the formula as log (a). For a formal treatment of the derivation of the exponents of (X) and (Y), reference should be made to the paper of Hechter (1959).

PROCEDURES

Subjects.

The subjects, chiefly Navy men, were selected to include extremes in weight and stature. They varied in weight from 117.5 kg (258.5 lb) to 52.4 kg (115.3 lb), and in height from 201.5 cm (79.5 in) to 161 cm (63.3 in). There were obese as well as lean individuals in the group.

Measurements.

Seven measurements (bideltoid diameter and circumferences of the chest, biceps, forearm, buttocks, thigh, and calf) were summated for

the calculation of body weights. The additional circumferences (waist, ankle, wrist, and knee) were employed subsequently in the partitional anthropometric analyses.

A Hrdlicka blade anthropometer was employed to measure the bideltoid diameter and a plastic tape for the circumferences. The ends of the tape were held firmly in all measurements, but the tension was not determined. The techniques employed (Air Force) were essentially those outlined by Hertzberg *et al.* (1954), with two modifications. The chest circumference was measured at the mid-point of the normal respiratory excursion (Air Force—maximal circumference during normal breathing), and the forearm (maximal circumference) measured with arm extended, hand open (Air Force—arm at right angles, hand closed). Essential characteristics of the other measurements were: biceps firmly contracted with the arm in maximal flexion; thigh circumference at the gluteal fold; maximal calf and minimal ankle and wrist circumferences; knee, tape drawn across the middle of the patella, with the knee slightly flexed to relax the patella; the waist was measured in a plane midway between the lowest margins of the ribs laterally and the superior margins of the iliac crests. This is usually the minimal abdominal circumference. Measurements were made on both the right and left extremities and the average values recorded.

It was considered that the one diameter (bideltoid) included could be determined more accurately than the shoulder circumference. This measurement, however, calls for an anthropometer, whereas all of the other dimensions require only a tape measure. In order to simplify the anthropometric procedure, one may eliminate the bideltoid diameter, or substitute the shoulder circumference.

Estimation of body fat.

This was based primarily on determinations of whole body density (d) utilizing the helium dilution chamber technique for body volume, and tritiated water (tritium) dilution for total body water (TBW), Siri (1956). The subjects' activities were not regulated with respect to fluid and mineral intake. Hence, although the techniques were carried out with care, the data cannot be regarded as precise. Siri has computed the probable error of estimate of total body fat from his combined formula which incorporates values both for density and total body determinations as $\pm$ 2 per cent body weight. His formula for the estimation of body fat from both total body water and whole body density is:

$$\% \text{ Fat} = \frac{213.66}{\text{density}} - 77.49 \left(\% \frac{\text{water}}{W} \right) - 137.4.$$

In this equation, the constants are based on values of 0.90 for the density of body fat, and 1.100 for the density of the fat-free body mass. The mean percentage of fat for the Navy group determined by these methods was ~19. Body fat was also estimated from the anthropometric measurements (*A-B* analysis) to be described in a subsequent paragraph.

Derivation of constants.

The body radius (R) for each of the 31 subjects in the Navy group was calculated from individual body weight and stature, *i.e.*, $R(W) = \sqrt{\frac{W}{\pi h}}$. From the sum of the individual body radii, the mean body radius $\bar{R}$ for the group of 31 men was found to be 1.178 decimeters. If we divide the mean values of each anthropometric measurement,

TABLE 1

Derivation of constants ("k" values) from Navy group dimensional measurements ($\bar{D}$) and mean body radius $\bar{R}$, for the calculation of body weights from anthropometric measurements.

$N = 31$, $\bar{h}$ 17.83 (dm), $\bar{W}$ 78.3 kg, *Median Value*, $W(m)$ 77.7 kg

Mean Body Radius, $\bar{R} = \sqrt{\frac{W(m)}{\pi h}} = 1.178$ dm

DIMENSIONS ($\bar{D}$)	MEAN VALUES (cm)	"k" VALUES ($D \div \bar{R}$)
Diameter		
Bideltoid	47.1	40.0
Circumferences		
Chest	95.9	81.4
Biceps	32.0	27.2
Forearm	27.9	23.7
Buttocks	97.5	82.8
Thigh	57.1	48.5
Calf	37.4	31.7
	$\Sigma\ \bar{D}$ 394.9	$\Sigma\ k$ 335.3
Additional Measurements:		
Circumferences		
Wrist	17.2	14.6
Knee	38.2	32.5
Ankle	22.5	19.1
Waist	83.4	70.8

($D(1)$, $D(2)$ etc.) by $\bar{R}$ (1.178 dm), we obtain the values of the conversion constants ($k(1)$, $k(2)$ etc.) for each dimension listed in table 1. The summated conversion constant (k) represents the sum of the constants for each dimension. The sum of the mean values of the anthropometric dimensions is 394.9 cm. This value divided by $\bar{R}$ also gives the value of the summated conversion constant k, and this amounts to 335.3.

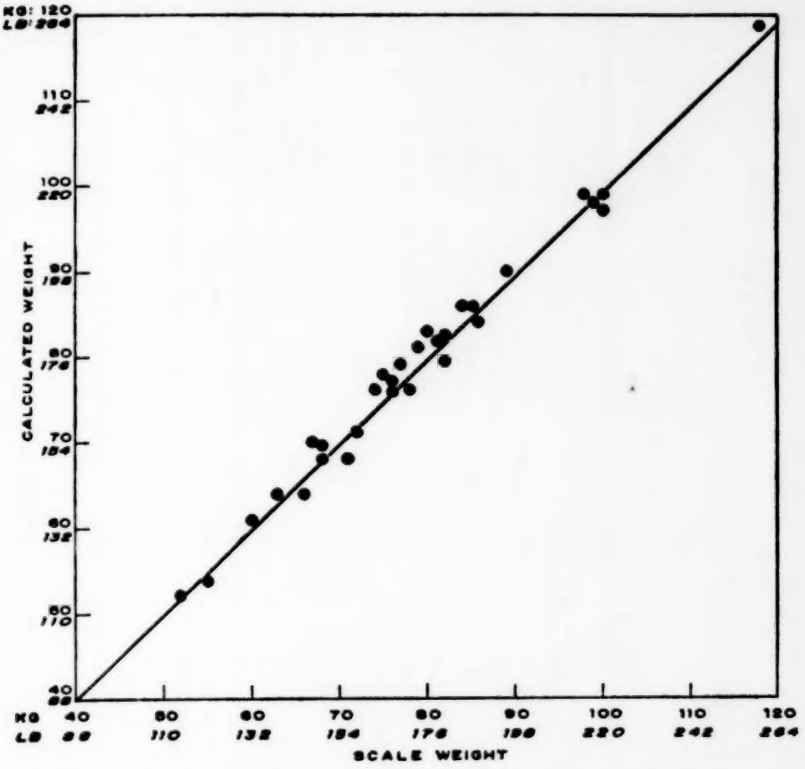

FIG. 2. Comparison of scale weights and weights of 31 men calculated from 7 anthropometric measurements (D) and stature (h). W (calc.) $= \pi R^2 h$, R is the body "radius" from $D \div$ by a constant (k).

RESULTS

Mean values for body weight and the anthropometric dimensions are shown in table 2, and for comparison, similar data on other groups are included. Garrison (1957) made an independent study of submarine personnel and employed techniques identical to those utilized in our study.

TABLE 2

Mean values of anthropometric dimensions (in cm) and body weights on young men

	STATURE dm	WEIGHT kg	BIDELTOID DIAMETER	CHEST	BICEPS	FOREARM CIRCUMFERENCES	BUTTOCKS	THIGH	CALF	WAIST
Navy ($N = 31$)	17.83	78.3	47.1	95.9	32.0	27.9	97.4	57.1	37.4	83.4
C. V.	(4.9)	(18.1)	(6.5)	(8.2)	(10.2)	(4.6)	(7.8)	(9.6)	(6.7)	(11.8)
Navy ($N = 44$)	17.63	75.1	44.0	95.3	33.4	28.2	96.9	55.7	37.2	81.9
Air Force ($N = 4000$)	17.55	74.4	45.4	98.6 [1]	32.5	29.2 [2]	96.0	56.9	36.6	81.4
C. V.	(3.5)	(12.7)	(5.1)	(6.3)	(8.3)	(6.4)	(6.1)	(7.8)	(6.7)	(9.4)
Athletes ($N = 50$)	17.53	76.2	49.1	104.9	37.6	31.5	95.3	56.6	37.9	78.7

Sources: Navy ($N = 31$) Behnke *et al.*, this report; *Navy* ($N = 44$) Garrison (1957); Air Force, Hertzberg *et al.* (1954); Athletes, Willoughby (1932).

[1] Maximal excursion during normal breathing.

[2] Arm flexed 90°, hand closed in a fist.

TABLE 3

Body weights on 12 of 31 subjects calculated from anthropometric dimensions (D) converted to a "body radius" (R). Estimates of percentage body fat were made from body density and water determinations, and from anthropometric measurements ($A - B$).

SUBJECT	AGE	STATURE (h) dm	ΣD cm	R ($\Sigma D \div 335.3$) dm	WEIGHT ($\pi R^2 h$) km	WEIGHT (Obs.) kg	BODY DENSITY	BODY WATER kg	WATER (% W)	% FAT [1]	% FAT ($A - B$)
1	34	20.15	460.2	1.373	119.3	117.5	1.020	54.6	46.4	36.2	28.3
2	52	17.88	445.1	1.328	99.1	100.0	1.033	49.6	49.6	31.0	21.2
22	48	17.75	442.7	1.320	97.1	100.0	1.020	57.6	57.6	27.5	27.4
4	31	18.03	439.9	1.312	97.5	98.9	1.014	48.3	48.8	35.5	34.4
13	39	18.80	433.2	1.292	98.6	98.4	1.040	53.5	54.4	25.8	20.7
21	22	17.65	400.9	1.196	79.3	77.0	1.052	50.6	65.7	14.8	17.3
24	31	19.35	398.9	1.190	86.1	83.9	1.047	48.3	57.6	19.2	12.2
20	31	17.73	389.4	1.161	75.1	75.9	1.053	48.0	63.2	16.5	18.7
3	21	17.93	369.3	1.101	68.3	67.7	1.083	45.3	66.9	8.1	15.0
27	20	16.20	364.8	1.087	60.2	61.1	1.063	36.3	59.4	17.6	15.4
17	20	16.10	346.9	1.034	54.1	54.8	1.081	34.3	62.6	11.8	3.7
28	23	17.18	335.2	1.000	54.0	52.4	1.074	32.4	61.8	13.6	8.7
$\bar{M}$ ($N = 31$)	29	17.83	395.0	1.178	78.5	78.3	1.051	46.0	58.6	19.5	18.8
C. V.		4.9	7.75			18.1		14.0			

[1] $\%\ \text{Fat} = \dfrac{213.66}{\text{density}} - 77.49 \left(\dfrac{\%\ \text{water}}{W}\right) - 137.4$ (Siri equation).

Representative data on the 31 subjects are given in table 3. All values for the 31 subjects are plotted in figure 2. The correlation between calculated and scale weights was found to be nearly unity, and the standard error of estimate was $\pm$ 1.64 kg (2.1% $\bar{W}$). Variation in the amounts of body fat in the range of 8 to 36% did not affect the accuracy of the estimations of weight.

Variability of intra-individual measurements.

The Standard Deviation of the differences between the body radius calculated from any single dimension, and the body radius computed for any given individual from the summated dimensions is shown by the following ($\pm$) values: bideltoid diameter (2.75), and the girths of the chest (2.68), biceps (4.82), forearm (3.35), buttocks (2.03), thigh (3.66), and calf (3.68). It is observed that the circumference of the buttocks is the best single dimension, together with stature, for the estimation of body weight.

Estimation of body fat from anthropometric data.

Measurements (A) of the body trunk, which harbor the large subcutaneous and intra-abodminal fat depots, may be compared with those of the extremities (B). These reflect primarily muscular development and, to a lesser degree, fat deposition. For comparative purposes, we again utilize the Navy group values and equate individual values with the group "k" values (table 4). The "trunk" measurements (A) include circumferences of the chest, abdomen, buttocks and, in addition, the thighs. The constant ($k(A)$) is the sum of the "k" values (taken from table 1) for each of the dimensions in group A, and is equal to 283.5. The radius ($R(A)$) is obtained from $A \div k(A)$, and body weight ($W(A)$) computed from group "A" is equal to $\pi(R(A))^2h$. The "extremity" measurements include the circumferences of the biceps, forearm, wrist, knee, calf and ankle, as well as the bideltoid diameter.

Likewise, for group "B" (table 4) the constant $k(B)$ is the sum of the previously derived "k" values for group B dimensions. $R(B)$ and $W(B)$ are calculated in the same way as $R(A)$ and $W(A)$.

The chest circumference presents a problem as to which category, "A" or "B," it belongs, since it may enlarge either by fat accretion or as a result of special muscular exercises, such as weight lifting. In Willoughby's athletes, for example, the difference between chest and waist girth is 26.2 cm compared with a corresponding difference of

12.5 cm for the Navy group. In the athletes, the abnormally large chest girth relative to that of the waist may be attributed to unusual muscular development and not to fat deposit. Therefore, when the radius (R), computed from the chest circumference, is greater than the radius (R) derived from waist girth, as in the athletes, the chest circumference is removed from category "A" and placed in "B." This serves to decrease the value of $k(A)$ in this case to 202.1, *i. e.* 283.5 — 81.4, and to increase $k(B)$ from 188.8 to 270.2.

The estimation of body fat from the two groups of measurements is based on the fact that the mean fat content in the Navy group is $\sim$19 per cent of body weight, and $\bar{W}(A) = \bar{W}(B)$. In a given individual, it is presumed also that when $W(A) = W(B)$, fat constitutes 19 per cent of the individual's body weight. The amount of excess fat below or above 19 per cent body weight is obtained by the difference between $W(A)$ and $W(B)$. The estimate of the total amount of excess fat for a given individual is therefore $0.19W + W(A) - W(B)$, as shown in table 4.

In table 2, selected data are recorded for estimates of body fat by means of the partitional analysis. The correlation ($r = 0.80$) obtained on the 31 men between body density values and the estimate of excess fat from the A-B analysis is perhaps no better at this time than the estimate of fat from skinfold measurements. However, it encourages further examination and simplification with a view of using several abdominal girths at different levels for comparison with the body radius. Area measurements from somatotype photographs of the lateral and posterior aspects of the trunk of the body would appear also to serve the same purpose.

Delineation of body pattern.

The deviations of single radii ($R(s)$) from the body radius (R) can be expressed in terms of percentages, *i. e.*, $R(s) \div R \times 100$, as shown in figure 3. A deviation of 6 per cent from R is equal approximately to 1σ. The occasional extreme inter-individual variability of certain dimensions is apparent from the data in table 4, and from figure 3. Thus, the radius calculated from the circumference of the biceps (1.518 dm) of subject 2 is greater by 13.8% than the subject's body radius. By contrast, the bicipetal radius of subject 4 (1.199 dm) is 8% smaller than his body radius and hence appears as a negative deviation on the abscissa scale of figure 3. Likewise, there is a big difference in the respective radii computed from the wrist measurements of the two

subjects. Noteworthy is the fact that both of these men have approximately the same body radius, weight, stature and content of total body water and fat.

TABLE 4

Estimation of body fat from anthropometric measurements in two subjects and in athletes (Willoughby, 1932) from the difference in body weights calculated from trunk—thigh (A) and bideltoid—extremity (B) dimensions

"k" VALUES	DIMENSIONS (D)		SUBJECT 2 D cm	SUBJECT 2 R dm	SUBJECT 4 D cm	SUBJECT 4 R dm	ATHLETES D cm	ATHLETES R dm
		h (dm)	17.88		18.02		17.53	
		W (dg)	100.0		98.9		76.2	
		R (dm)	1.334		1.322		1.176	
	"A" GROUP						$k(A) = 202.1$	
81.4	Chest		108.0	1.327	109.6	1.346	—	—
82.8	Buttocks		108.0	1.304	108.0	1.304	95.3	1.151
48.5	Thigh		64.2	1.324	67.7	1.400	56.6	1.167
70.8	Abdomen		100.7	1.415	99.1	1.400	78.7	1.112
$k(A)$ 283.5			380.4		384.4		230.6	
	$R(A) = A \div k(A)$			1.342		1.356		1.141
	$W(A)$			101.1		104.1		71.7
	"B" GROUP						$k(B) = 270.2$	
	Chest		—		—		104.9	1.288
40.0	Bideltoid		51.3	1.283	51.5	1.288	49.1	1.288
27.2	Biceps		41.3	1.518	32.6	1.199	37.6	1.382
23.7	Forearm		31.9	1.346	27.3	1.152	31.5	1.329
14.6	Wrist		19.4	1.329	16.6	1.137	18.0	1.233
32.5	Knee		43.3	1.332	40.7	1.252	37.5	1.154
31.7	Calf		40.4	1.274	43.2	1.363	37.9	1.196
19.1	Ankle		23.8	1.246	25.6	1.340	22.4	1.173
$k(B)$ 188.8			251.4		237.5		338.9	
	$R(B) = B \div k(B)$			1.332		1.258		1.254
	$W(B)$			99.6		89.6		86.6
	$W(A) - W(B)$			+1.5		+14.5		—14.9
	19% Scale Weight			19.0		18.8		14.5
	Excess Fat (kg)			20.5		33.3		—00.4

REFERENCE MAN AND WOMAN

From various sources listed in tables 5 and 6, it has been possible to cull comparable data in which anthropometric measurements have been made in a consistently uniform maner. Some deviation in measurement procedure in the different groups may be noted with reference to

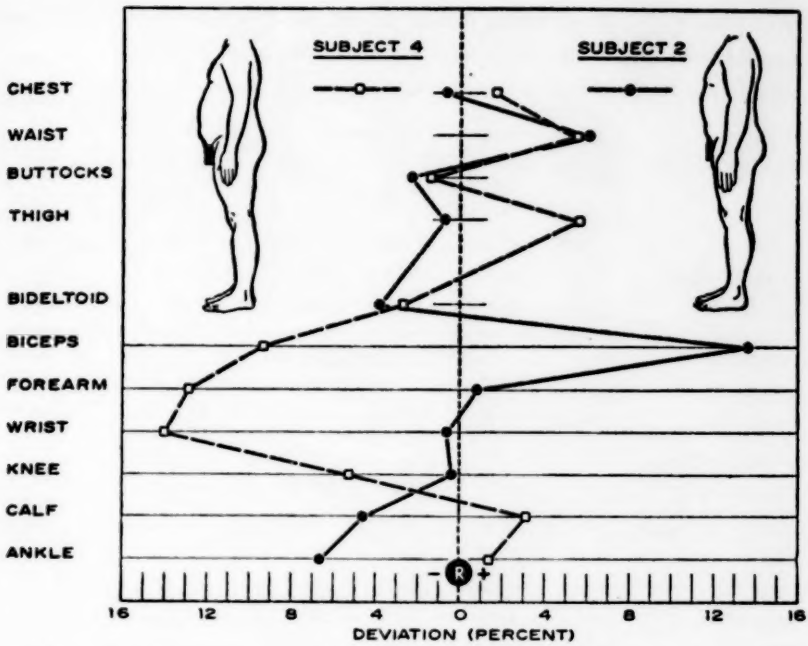

FIG. 3. Body patterns showing percentage deviation from body radius *R* calculated for each subject from his body weight, of single anthropometric dimensions converted to their respective radii in two individuals showing marked differences in musculature, reflected mainly in arm size.

the chest (*e. g.*, girth recorded either during the maximal or mid-phase of the normal respiratory excursion) and to the forearm (arm extended with hand open, or flexed 90° with the hand doubled into a fist). Since errors of measurement are raised to the second power in the calculations, it is mandatory in future studies to define precisely not only anatomical landmarks for such girths as shoulder and chest circumferences, but to employ a tape measure which registers also the desired tension which is applied to the tape. Despite these shortcomings it is observed that the "*k*" values recorded in the tables are remarkably consistent and

they do not deviate too far from the constants derived from the Navy data.

TABLE 5

Derivation of proportionality constants (k values) for a reference man from several sources. The values for k are obtained by dividing the mean values for each dimension by $\bar{R}$, the mean body radius. The $\bar{R}$ value for each group is derived from $\sqrt{\frac{W}{\pi h}}$, W represents median weight and h, mean stature. The mean values for each dimension can be calculated from the product $k\bar{R}$.

	ARMY [1]	NAVY	AIR FORCE [2]		WILLOUGHBY [3]	REFERENCE MAN
N	25,000	31	4,000	3,000	52	
$\bar{R}$ (dm)	1.128	1.178 [a]	1.155	1.100	1.171	1.126
h (dm)	17.39	17.83	17.55	17.41	17.53	17.40
Median W (kg)	69.5	77.7 [b]	73.6	66.1	75.5 [b]	69.3
Mean W	70.4	78.3	74.4	66.9	76.2	70.0
DIMENSIONS	k Values ($D_{(cm)} \div \bar{R}$)					
Diameter						
Bideltoid	40.4	40.0	39.3	—	41.9	40.0
Circumferences						
Shoulders	—	—	(99.5)	(98.2)	—	—
Chest	81.9	81.4	85.4 [c]	82.1	89.6	82.0
Biceps	—	27.2	28.1	28.1	32.1	28.1
Forearm	—	23.7 [d]	25.3 [e]	24.6 [e]	26.9 [d]	24.6 [e]
Buttocks	82.4	82.8	83.1	83.9	81.4	82.8
Thigh	48.3	48.5	49.3	49.4	48.3	48.8
Calf	31.7	31.7	31.7	32.0	32.4	31.7
$\bar{M}$		335.3	342.2		352.6	338.0
Waist	69.0	70.8	70.5	70.0	67.2	69.0

Sources: [1] Quartermaster General Report No. 180 (1951); [2] $N = 4{,}000$, Hertzberg *et al.* (1954), $N = 3{,}000$, Daniels *et al.* (1953); [3] Willoughby (1932).

[a] For the Navy group, $\bar{R}$ was the mean of 31 individual R values calculated from $\sqrt{\frac{W}{\pi h}}$.

[b] Calculated from $\pi \bar{R}^2 h$.

[c] Maximal circumference during normal breathing.

[d] Arm extended, hand open.

[e] Arm flexed 90°, hand closed.

TABLE 6

Derivation of proportionality constants (k values) for a reference woman from several sources (see caption, table 5)

	WAF TRAINEES [1]	USDA WOMEN [2]	USDA GIRLS,[3] AGE 17	WILLOUGHBY [4]	REFERENCE WOMAN
N	852	10,041	2771	20	—
R(dm)	1.042	1.073	1.027	1.045	1.047
$\bar{h}$(dm)	16.27	16.05	16.11	16.27	16.38
W(kg) (median)	55.5	58.5	—	—	56.4
$\bar{W}$(kg)	56.0	60.7	53.4	55.8	56.8
		$k(D_{(cm)} \div \bar{R})$ values			
Circumferences					
Shoulders	92.1	—	—	—	92.1
Chest [a]	78.8	—	—	—	78.8
Upper arm [b]	26.8	26.9	24.2	—	26.8
Biceps (flexed)	25.6	—	—	27.0	25.6
Forearm	23.1	23.1	—	23.1	23.1 [c]
Buttocks	90.0	91.9	89.9	90.0	90.0
Thigh	53.3	52.6	52.1	52.7	52.6
Calf	32.7	31.8	32.4	32.5	32.5
Waist	64.5	69.0	62.9	63.0	

Sources: [1] Daniels *et al.* (1953); [2] O'Brien *et al.* (1941); [3] O'Brien *et al.* (1941); [4] Willoughby (1932).

[a] Chest, arm scye level and above mammary glands.
[b] Axillary arm circumference.
[c] Arm flexed 90°, hand closed.

If a value of 69.3 kg (the median weight of a "reference" group), and a stature of 17.40 dm be selected for a reference man, then his body radius will be 1.126 dm. The values in table 7 for certain dimensions (D) for this man can be calculated from the product of $R \times D$(cm). Likewise, similar dimensional measurements can be calculated for a "reference" woman whose weight is 56.4 kg and stature 16.38 dm.

Male and female complementary measurements.

In table 7 it is seen that the sum of the "k" values for a reference man and woman are nearly equal, although the constants for a given dimension may differ considerably in the two sexes. Thus, the greater shoulder circumference of the man relative to his size is indicated by the

TABLE 7

Complementary relationships between anthropometric dimensions for a reference man and woman based on the summated values of their weight conversion constants (k values).

GROUP DATA	REFERENCE MAN		REFERENCE WOMAN	
Age	22		18 to 25	
Stature $\bar{h}$ (dm)	17.40 (68.5 in)		16.38 (64.5 in)	
Weight (kg)				
Median	69.3 (152.5 lb)		56.4 (124 lb)	
Mean	70.0 (154.0 lb)		56.8 (125 lb)	
Body Radius ($\bar{R}$) $= \sqrt{\frac{W\ (\text{median})}{\pi \bar{h}}}$	1.126 (dm)		1.047 (dm)	
INDIVIDUAL DATA DIMENSIONS (D)	D (cm)	k VALUES ($D \div \bar{R}$)	D (cm)	k VALUES ($D \div \bar{R}$)
Shoulders	111.5	99 } 181.8	96.4	92.1 } 182.1
Buttocks	93.2	82.8 }	94.2	90.0 }
Biceps	31.6	28.1 } 133.2	26.8	25.6 } 133.8
Forearm	27.7	24.6	24.2	23.1
Thigh	54.9	48.8	55.1	52.6
Calf	35.7	31.7	34.0	32.5
	Σ 354.6	315.0	Σ 330.7	315.9
Adidtional circumferences				
Chest (arm scye level)	96.8	86	82.5	78.8
Waist	77.7	69	66.0	63.0

"k" value of 99, compared with the corresponding value of 92.1 for the woman. On the other hand, the relatively larger circumference of the hips of the woman compared with that of the man is evident from the respective "k" values of 90 and 82.8. The sum of the "k" values, however, for these two dimensions is equal for the man and the woman. We have applied the term "complementary" to this relationship. Upper and lower extremity girth measurements for the two sexes are likewise complementary. These reciprocal relationships may be expressed as:

$$\frac{\text{Woman}\ \dfrac{k\ (\text{shoulders})}{k\ (\text{hips})}}{k\begin{cases}\text{biceps}\\ \text{forearm}\end{cases}} = \frac{\text{Man}\ \dfrac{k\ (\text{hips})}{k\ (\text{shoulders})}}{k\begin{cases}\text{calf}\\ \text{thigh}\end{cases}}$$

DATA ON OTHER GROUPS

As a test of the general applicability of the anthropometric conversion constants ("*k*" values), it was of interest to analyze measurements of the circumferences of the calf on military personnel in Yugoslavia (1957) and in Russia (1883). The calf circumference was chosen primarily because it is amenable to a uniform technique of measurement despite the fact that intra-individual variation with respect to other dimensions is large. In this regard it approaches the biceps in that it can be altered by certain types of muscular exercise. Since some concern at times has been expressed in regard to possible disuse atrophy of the lower extremities in a mechanized American population, it was of interest further to examine data on groups of men who might be expected to have unusually well developed lower extremities.

In the Yugoslavian data, only mean values were available on commissioned and non-commissioned Army officers; weight (69.0 kg), stature (17.20 dm), and calf girth (25.84 cm). If this calf girth is then divided by the conversion constant (31.7) for the reference man, the body radius computed from this single dimension is 1.1305 dm, and caluculated body weight from $\pi R^2 h = 69.1$ kg.

The Russian data were obtained from individual measurements recorded on soldiers by Kupriyanoff in 1883. The "*k*" values for the chest and calf girths of the reference man were used to predict body weight from these combined anthropometric values (table 8). Kupriyanoff also computed a body radius. Some principles in his paper, as well as in the reports of Willoughby (1932) and Turner (1943), are woven into the analyses of this paper.

GEOMETRICAL REPRESENTATION OF THE BODY

We have compared the body to a cylinder and established the reality of a body radius, R, in terms of anthropometric-weight (volume) relationships. The question arises, what is the surface area of the body, of specified radius R, and stature, in terms of the cylinder analogue. As previously stated, surface area is extremely tedious to measure, but it can be calculated rather well from the DuBois general formula (DuBois and DuBois, 1915):

$$A = W^a \times h \times K.$$

As commonly employed, the value of the exponent a is 0.425, and b, 0.725. However, "the formula, $A = W^{.5} \times H^{.5} \times 167.2$ was almost

as "good," *i. e.* the surface area of the body is proportional to the square root of the product of W and H. If this is so, one may derive from the

TABLE 8

Calculated body weights of Russian soldiers from anthropometric measurements made in 1883 [1] *based on constants derived from similar data on American military personnel in 1957.*

	HEIGHT	CIRCUMFERENCES		CALCULATED WEIGHT (kg) [2] from		AVERAGE	SCALE WEIGHT
		Chest	Calf				
	(dm)	(cm)	(cm)	(1), (2)	(1), (3)	(4), (5)	(kg)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	17.76	95.4	37.2	75.6	77.0	76.3	74.1
	17.37	91.0	35.5	67.2	68.5	67.9	67.6
	16.81	93.2	35.5	68.3	66.3	67.3	68.8
	17.32	94.3	37.2	72.0	74.8	73.4	73.7
	16.70	93.2	35.5	64.0	65.2	64.6	61.4
	15.37	86.6	33.8	53.9	54.2	54.1	57.7
	15.54	88.5	33.3	53.1	53.9	53.5	56.1
	15.65	86.6	34.4	54.7	57.9	55.3	59.0
	15.81	84.4	34.9	52.1	60.2	56.1	56.9
	15.87	84.4	34.4	52.8	58.7	56.0	56.5
	15.98	86.6	33.8	56.0	57.0	56.5	57.3
	16.26	88.8	34.4	61.4	60.2	60.8	58.1
	16.37	89.9	33.8	61.8	58.5	60.2	61.4
	16.59	89.9	35.5	62.6	65.4	64.0	64.7
	16.81	94.3	33.3	69.8	58.3	64.0	64.7
	17.09	90.5	37.7	65.4	75.9	70.7	70.4
	17.20	93.8	38.8	70.7	81.0	76.4	79.4
	17.59	94.3	36.6	73.1	73.6	73.4	77.8
	16.93	91.0	36.6	65.5	70.9	68.2	67.2
	17.15	86.6	34.4	60.1	63.4	61.8	65.5
	17.76	98.8	40.0	81.0	88.8	84.9	85.2
M	16.66	90.6	35.6	63.9	66.1	65.0	65.9
C.V. %	4.8	4.2	5.9	—	—	13.1	12.2

[1] Source: Kupriyanoff, 1890-91.

[2] Calc. $W = \pi R^2 h$, $R(\text{dm}) = \frac{\text{Chest C.}}{82.0}$ or $\frac{\text{Calf C.}}{31.7}$.

analysis of data furnished by one of the authors (A. R. B.) to von Schelling (1954) an expression for surface area in terms of R, the body radius, and h, stature, such that

$$A = 3\pi Rh = 2R \times 1.5h$$

Thus, the surface area of the body whose radius R is equal to a cylinder of radius r, can be represented by the cylindrical area ($2\pi r \times 1.5h$) of a second cylinder of the same radius as the first cylinder, but 1.5 times greater in height, figure 4.

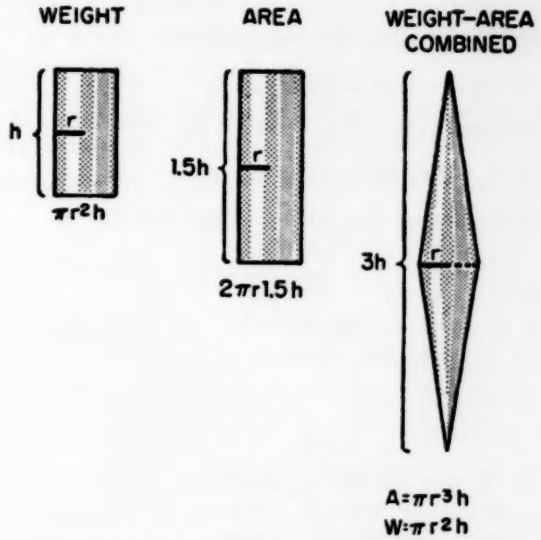

FIG. 4. Geometrical analogues of the body. Equivalent body weight for a given stature (h) may be represented by the volume of a cylinder with radius r and body area by the cylindrical area of a second cylinder (radius r), but 1.5 times longer than the first cylinder. The double cones (von Schelling) incorporate the body weight-area relationship in the same model. The long axis of this model, however, is 3 times body stature.

It can be shown also that both volume and surface area relationships characteristic of the human body can be represented by von Schelling's double cone model, figure 4. Data for surface area of large individuals were calculated on the basis of $A = 3\pi Rh$, and they are compared with values calculated by Sendroy and Cecchini (1954) from their formula and the formulas of DuBois and Boyd, table 9.

COMMENTS

The constant, π, in the formulas, $W = \pi R^2 h$ and $A = 3\pi Rh$, can be eliminated by dividing the "k" values in the tables by $\sqrt{\pi}$ and π respectively. Thus, since $\frac{D}{k}$, and $k = 335.3$ for the Navy group (table 1),

$k \div \sqrt{\pi} = 189.2$, so that

$$W(\text{kg}) = \left(\frac{D}{189.2}\right)^2 h = 2.794 \times 10^{-5} D^2 h, \; D \text{ in cm}, \; h \text{ in dm}.$$

Likewise, surface area (sq. dm) $= 3\pi Rh = 2.81Dh$, SA in sq. cm.

From the buttocks circumference ($D(b)$):

Male: $W(\text{kg}) = 4.58 \times 10^{-4} D^2(b)h$

Surface area (sq. cm) $= 1.138D(b)h$.

Female: $W(\text{kg}) = 3.88 \times 10^{-4} D^2(b)h$

Surface area (sq. cm) $= 1.047D(b)h$.

TABLE 9

***Surface area estimated for individuals of large stature from the formula, $A = 3\pi Rh$, and from other formulas by Sendroy and Cecchini* (1954)**

			SURFACE AREA (m^2)			
SUBJECT	H (cm)	W (kg)	DuBois	$3\pi Rh$ [1]	Boyd	Sendroy *et al.*
A	197.5	115.5	2.50	2.54	2.51	2.47
B	208.3	109.1	2.54	2.53	2.47	2.45
C	200.7	109.1	2.47	2.49	2.45	2.41
E	261.6	232.3	4.12	4.14	3.97	4.24
I	203.2	90.0	2.29	2.27	2.21	2.20
K	200.7	84.1	2.21	2.18	2.12	2.15
O(a)	182.9	80.8	2.03	2.04	2.02	2.00
O(c)	259.1	197.4	3.82	3.81	3.64	3.84
O(e)	268.0	222.8	4.13	4.11	3.92	4.23

[1] Values in sq. decimeters divided by 100.

SUMMARY

1. In a group of 31 Navy men it was shown that body weights could be calculated accurately from circumferential anthropometric measurements (D) mainly, and stature (h).

2. D divided by a constant (k) $= R$, the "radius" of the body, and $W = \pi R^2 h$.

3. Surface area in turn is equal to $3\pi Rh$.

4. The weight, surface area formulas may be rearranged to eliminate the constant, π, so that

$$W = D^2hk \text{ and } A = Dkh.$$

5. The number of measurements required to estimate weight and surface area may be reduced to two (girth of hips and stature) without introducing appreciable error.

6. Consistent anthropometric data were obtained on both men and women and from the dimensional conversion constants ("k" values) the following complementary relationships were revealed:

$$\frac{\text{Woman}}{\dfrac{k\,(\text{shoulders})}{k\,(\text{hips})}} = \frac{\text{Man}}{\dfrac{k\,(\text{hips})}{k\,(\text{shoulders})}}$$

$$\frac{k\begin{cases}\text{biceps}\\\text{forearm}\end{cases}}{k\begin{cases}\text{calf}\\\text{thigh}\end{cases}} = \frac{k\begin{cases}\text{calf}\\\text{thigh}\end{cases}}{k\begin{cases}\text{biceps}\\\text{forearm}\end{cases}}$$

7. Anthropometric measurements translated into their weight equivalents make possible a representation of body configuration.

8. Constants derived from the Navy data for the estimation of body weight from calf and chest circumferences were applicable to similar data obtained on Russian soldiers in 1883.

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THE RELATIONSHIP BETWEEN WEIGHT AND SOME ANTHROPOMETRIC MEASUREMENTS IN ADULT MALES

H. HECHTER

U. S. Naval Radiological Defense Laboratory
San Francisco 24, California

THERE have been a number of attempts to derive a functional relationship between weight (total or lean body) and a set of concomitant anthropometric measurements. The difficulties involved in determining the lean body weight makes this approach especially useful. Often the body weight has been expressed as a linear combination of the anthropometric variables (Brožek, 1956; Turner, 1943; McCloy, 1936), other authors (Massler, 1945; Günther, 1948), using a dimensional analysis, have expressed the body weight as being proportional to the product of two variables each raised to an appropriate exponent. Behnke, et al., (1959) have used a combination of these methods by assuming that the weight is proportional to the product of stature and the square of the sum of a number of anthropometric measurements. This paper derives a simple dimensional relationship and indicates the relative importance of the anthropometric variables which were used. The relationship will be indicated for the total body weight first and later in the paper for the lean body weight. The analysis is based on the measurements made by Behnke *et al.*, (1959) and of Behnke (1959) on a sample of 31 male individuals (age range—20 to 52 years) they have kindly furnished for this purpose. Reference is made to their papers for the discussion of the procedures and techniques involved in taking the measurements.

PREDICTION OF TOTAL BODY WEIGHT

The mean and standard deviation for the variables used in the regression analysis are given in table 1. With the exception of stature and the bideltoid measurement, all concomitant variables are circumferential.

Presuming the body weight to be proportional to body volume, a formula of the form

$$W = k_1 m_1^{a_1} m_2^{a_2} \ldots m_p^{a_p} \qquad (1)$$

was chosen to represent the relationship. Here (W) is the total body weight in kg, (m_i) is the i^{th} measurement in cm, and the exponents (a_i) are constants.

TABLE 1

Mean and standard deviation of the anthropometric measurements

	MEAN	STANDARD DEVIATION
Body Weight (kg)	78.3	14.5
Bideltoid (cm)	47.1	3.3
Chest (cm)	95.9	7.7
Xyphoid (cm)	91.3	8.3
Biceps (cm)	32.0	3.4
Forearm (cm)	27.9	1.8
Buttocks (cm)	97.4	7.4
Thigh (cm)	57.1	5.3
Calf (cm)	37.4	2.4
Stature (cm)	178.3	8.7

TABLE 2

Estimate of the coefficients using all of the measurements

VARIABLE	COEFFICIENT	ESTIMATE ± STANDARD ERROR
Bideltoid	a_1	0.21 ± 0.12
Chest	a_2	0.45 ± 0.24
Xyphoid	a_3	0.08 ± 0.21
Biceps	a_4	0.04 ± 0.10
Forearm	a_5	0.31 ± 0.12
Buttocks	a_6	0.57 ± 0.18
Thigh	a_7	0.41 ± 0.16
Calf	a_8	0.09 ± 0.14
Stature	a_9	0.65 ± 0.10
R		0.996
CV		2.0%

The variables were transformed into logarithmic form,[1] and from this equation the constants were estimated by the method of least squares. The estimate of the constants or coefficients is shown in table 2.

R, the multiple correlation coefficient, is a measure of the degree of association between the total body weight (logs) and the measurements

[1] $y = k + a_1x_1 + a_2x_2 + \cdots + a_9x_9$ where $y = \log W$; $x_i = \log m_i$; $k = \log k_1$.

(logs) considered jointly. *CV*, the coefficient of variation, is a measure of the % variability in total body weight when the measurements have been taken into account.

There are three main points which can be inferred from table 2.

1. There is an extremely close degree of association between body weight and the variables when expressed in the functional form given by (1).

2. Some of the variables do not contribute significantly or appreciably to the prediction of body weight when in the presence of the other variables.

3. The sum of the coefficients or exponents is approximately equal to three, indicating that the body weight is adequately described by a volume or by a product of linear dimensions whose powers add to three.

When those variables which are of little or no predictive importance are eliminated, there is left an equation which includes only three of the 9 variables, viz.

$$W = k_1 m_2^{a_2} m_6^{a_6} m_9^{a_9} \qquad (2)$$

Table 3 gives the estimate of the coefficients for the reduced equation (2).

TABLE 3

Estimate of the coefficients of the reduced equation

VARIABLE	COEFFICIENT	ESTIMATE ± STANDARD ERROR
Chest	a_2	0.84 ± 0.15
Buttocks	a_6	1.14 ± 0.15
Stature	a_9	0.87 ± 0.12
R		0.989
CV		2.8%

It is seen that the use of three measurements instead of 9 results in a very slight decrease in precision. (For *R*, compare 0.996 with 0.989 and for *CV*, compare 2.0% with 2.8%). Further, the coefficients are not significantly different from unity (see table 4), thus indicating that body weight can be predicted from a simple formula of the form

$$W = k_1 m_2 m_6 m_9 \qquad (3)$$

or

$$W = 466 \times 10^{-7}\ C \cdot B \cdot S \qquad (4)$$

where $C = m_2 =$ Chest circumference
$B = m_6 =$ Buttocks circumference
$S = m_9 =$ Stature.

TABLE 4

Test of the hypothesis of $a_2 = a_6 = a_9 = 1$

VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	*F*
Deviation from $a_2 = a_6 = a_9 = 1$	3	0.00014	1.0 (not significant)
Residual	27	0.00014	
Total	30		

It is of interest to determine how much precision is sacrificed if only two measurements, stature and one other, are used. Table 5 gives the estimate of the coefficients and coefficient of variation.

TABLE 5

Estimate of the coefficients when two variables are used

STATURE AND	BUTTOCKS	XYPHOID	CHEST	CALF	THIGH	FOREARM	BIDELTOID
0.90	1.91						
1.15		1.73					
1.04			1.80				
1.06				1.94			
0.70					1.59		
0.96						1.92	
1.00							2.07
CV	4.0%	6.1%	5.0%	8.8%	4.8%	9.0%	8.1%

None of the coefficients is significantly different from its closest integer, indicating that a simple formula of the form

$$W = k_i m_i^2 m_9 \qquad (5)$$

where m_9 is the stature and m_i is the buttocks, chest, calf, thigh, forearm, bideltoid or xyphoid, could be used as a prediction formula. However, the

variability for any combination, as shown in the last line of table 5, is significantly increased as compared to the preceding expression, formula (4), which utilizes three linear dimensions.

PREDICTION OF LEAN BODY WEIGHT

For each of the 31 individuals, determinations of the body density and total body water were made (Siri, 1957). From these determinations, an estimate of the lean body weight was calculated from a modified form of the equation given by Siri (1956). Reference is made to the papers of Behnke (1959), and Siri (1956) for the discussion of the applicability and validity of the methods. Here it suffices to note that there are a number of uncertainties involved in the method of calculating the lean body weight. The reliability of the method as expressed as a coefficient of variation is roughly estimated as 2–3% (Siri, 1956).

TABLE 6

Mean and standard deviation of the skeletal diameters

	MEAN	STANDARD DEVIATION
Lean Body Weight (kg)	63.6	8.8
Biacromial (cm)	40.6	1.9
Chest (cm)	29.9	1.9
Bi-iliac (cm)	29.4	2.3
Bitrochanteric (cm)	32.8	2.3
Wrist (cm)	5.6	0.4
Ankle (cm)	6.9	0.3
Knee (cm)	9.2	0.7
Stature (cm)	178.3	8.7

As in the preceding section on total body weight, it is assumed that a general formula of the form

$$L = c_1 t_1^{\beta_1} t_2^{\beta_2} \cdot \cdot \cdot t_8^{\beta_8} \qquad (6)$$

where L = lean body weight, t_i is the i^{th} skeletal measurement, would adequately describe the relationship between lean body weight and a set of skeletal diameters. The skeletal diameters that were used in the analysis, along with their mean and standard deviation are shown in table 6. The estimate of the β coefficients are given in table 7.

It is seen in table 7 that some of the skeletal variables are of little or no importance for the prediction of lean body weight. When these

variables are eliminated, there is left a formula based on the product of three linear dimensions. See table 8 for the estimate of the coefficients.

TABLE 7

Estimates of the coefficients using all of the skeletal diameters

SKELETAL DIAMETER	COEFFICIENT	ESTIMATE ± S. E
Biacromial	β_1	—0.04 ± 0.58
Chest	β_2	0.72 ± 0.47
Bi-iliac	β_3	—0.34 ± 0.47
Bitrochanteric	β_4	0.72 ± 0.50
Wrist	β_5	0.39 ± 0.28
Ankle	β_6	—0.18 ± 0.46
Knee	β_7	—0.08 ± 0.30
Stature	β_8	1.17 ± 0.38
R		0.85
CV		8.1%

TABLE 8

Estimate of the coefficients of the reduced equation

SKELETAL DIAMETER	COEFFICIENT	ESTIMATE ± S. E.
Chest	β_2	0.75 ± 0.33
Wrist	β_5	0.43 ± 0.33
Stature	β_8	1.18 ± 0.34
R		0.84
CV		7.8%

Thus, the formula for predicting lean body weight can be written

$$L = 519 \times 10^{-5} C_d^{0.75} W_d^{0.43} S^{1.18} \qquad (7)$$

where C_d = Chest diameter

W_d = Wrist diameter

S = Stature

and this formula is practically as precise for predicting the lean body weight as the formula which uses all of the skeletal diameters.

On 23 of the 31 individuals, radiographic skeletal measurements were obtained. To determine whether these X-ray measurements would give a closer degree of association with lean body weight than do the skeletal diameters, a regression analysis was made. The mean and standard deviation are listed in table 9.

The multiple correlation coefficient between lean body weight and the 9 x-ray variables and stature was 0.92. Most of the variables were of little or no predictive importance, and table 10 shows the estimate of the exponents or coefficients of the reduced equation. The estimates when the skeletal diameters are used (table 8) are also shown.

TABLE 9

Mean and standard deviation of the x-ray measurements and stature

	MEAN	STANDARD DEVIATION
Lean Body Weight (kg)	64.0	8.8
Elbow (cm)	6.3	0.4
Wrist (cm)	4.9	0.4
Knee (cm)	8.8	0.5
Ankle (cm)	6.5	0.3
Proximal Tibia (cm)	8.1	0.4
Distal Tibia (cm)	5.3	0.3
Bi-iliac (cm)	27.9	2.4
Bitrochanteric (cm)	30.5	2.2
Chest (cm)	28.1	1.6
Stature (cm)	178.7	9.6

TABLE 10

Estimate of the coefficients

SKELETAL DIAMETER	ESTIMATE ± S. E.	X-RAY MEASUREMENT	ESTIMATE ± S. E.
Chest	0.75 ± 0.33	Chest	0.75 ± 0.25
Wrist	0.43 ± 0.33	Wrist	0.43 ± 0.20
Stature	1.18 ± 0.34	Stature	1.30 ± 0.29
R	0.84		0.90
CV	7.8%		6.5%

As seen in table 10, the use of x-ray measurements for predicting lean body weight is slightly better than the use of skeletal diameters. As mentioned earlier, there are a number of uncertainties involved in determining the lean body weight by use of the body density and total body water, and this might be one of the possible reasons for the failure of the sum of the exponents to add to three.

The formula for the prediction of lean body weight from the x-ray measurements is

$$L = 300 \times 10^{-5} C_x^{0.75} W_x^{0.43} S^{1.30} \quad (8)$$

where C_x = Chest x-ray
W_x = Wrist x-ray
S = Stature.

SUMMARY

Using statistical regression analysis, equations have been derived for predicting weight (either total or lean body) in adult males from body measurements. The predictive equations and the multiple correlation coefficient, R, are as follows:

a. Total body weight

$$W = 466 \times 10^{-6}\ C \cdot B \cdot S$$

where W = total body wt. in kg
C = chest circumference in cm
B = buttocks circumference in cm
S = stature in cm
and $R = 0.99$

b. Lean body weight

(i) from skeletal diameters

$$L = 519 \times 10^{-5} C_d^{0.75} W_d^{0.43} S^{1.18}$$

where L = lean body wt. in kg
C_d = chest diameter
W_d = wrist diameter
S = stature
and $R = 0.84$

(ii) from x-ray measurements

$$L = 300 \times 10^{-5} C_x^{0.75} W_x^{0.43} S^{1.30}$$

where C_x = chest x-ray
W_x = wrist x-ray
S = stature.
and $R = 0.90$

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DATA ON THE BIOLOGY OF KOREAN POPULATIONS [1]

BY YUNG SUN KANG AND WAN KYOO CHO

Department of Zoology
Seoul National University, Seoul, Korea

APART from scattered references in the economic and sociological literature there are few, if any, data available on some of the characteristics of Korean populations that are fundamental to various problems of human genetics. Information on birth and death rates as related to socio-economic groups are of potential value for considerations of gene frequencies in successive generations. Such information is at present mostly restricted to Western countries. The secondary sex-ratio is known to vary from one group to another and its supposedly unusually high value in Korea deserves checking. The frequency of twins, and their types, is known to be different in Japan and Western countries and data on other Asian groups are desirable in order to form a judgment on the generality of the differences. Finally, the topic of consanguinity is at present under intense study by various investigators for an estimate of the genetic structure of populations and individuals, and data on frequency and types of consanguinity form one of the bases for further investigations. In order to contribute to these topics, material is presented in this report on samples of the Korean population on birth and death rates, the secondary sex ratio, frequency and types of twins and frequency and types of first cousin marriages.

METHODS

The data pertain to populations living in the city of Seoul, Cheju Island, Ulnung Island and a series of 27 cities and towns with less than 100,000 inhabitants. By means of a simple printed questionnaire, the following information was obtained, mostly from middle and high school students:

1. Occupation of father,

[1] The authors are greatly indebted to Professor C. Stern, Department of Zoology, University of California, who read the manuscript and gave us valuable advice. The financial aid given by the Asian Foundation is also acknowledged here.

2. Number of family members (parents and children on March 31, 1956, according to sex and age in decades from 0 to 81+ years),

3. Numbers of births and deaths, according to sex and age within a specified period (see below),

4. Numbers of twin pairs and sex of twins,

5. Numbers of first cousin marriages of brothers (during the period from August 1, 1953 to July 31, 1956) and relation of wife to husband through father's or mother's brother or sister.

Two different periods were covered by the questionnaire. For the city of Seoul and Cheju Island numbers of births and deaths were determined for the period April 1, 1955 to March 31, 1956 and for the series of 27 other localities the period comprised April 1, 1956 to March 31, 1957. Information on consanguineous marriages in all cases covered the three year period stated above.

This questionnaire was given to 18,227 male and female students in middle and high schools located in Seoul and Cheju. Seventeen of these schools were in Seoul. They form a random selection from the 50 or more Seoul schools. Eleven schools were on Cheju. They were selected from the twenty schools on the islands on the basis of choosing one school from one locality only.

For the small island Ulnung, one of the authors himself visited each of the 280 houses and personally obtained answers to the questionnaire.

It should be added that information on adopted children was not included in the data.

It may be assumed that the students questioned represented not only a random sample of the school population but of the population in general since there is universal education in Korea. Evidence for this statement is found in the "Statistical Yearbook of the Republic of Korea" (1957) which gives the total population of the country as approximately 20 million and that of students as about 4 million or 20% of the population.

RESULTS

Birth and Death Rates

Table 1 contains data on births and deaths in Seoul, Cheju and Ulnung Islands. In the urban environment of Seoul the death rate is significantly higher than the birth rate. On Cheju too, the death rate is higher than the birth rate, but the difference is not significant. On

Ulnung, the birth rate greatly exceeds the death rate, the difference being highly significant in spite of the smallness of the population.

The relatively low birth rate in Seoul is not unlike that of other large cities. It is undoubtedly influenced by control of conceptions. On Cheju the population consists largely of families of fishers. Here the relatively low birth rate may be correlated with the fact that the men are absent from home for long periods during fishing expeditions.

TABLE 1

AREAS	POPULATION	NO. OF BIRTHS	RATES OF BIRTH—%	NO. OF DEATHS	RATES OF DEATH—%
Seoul	102,673	1,285	12.52 ± 0.35	1.580	15.39 ± 0.38
Cheju	21,708	357	16.45 ± 0.87	328	15.11 ± 0.83
Ulnung	1,563	81	51.82 ± 5.61	19	12.16 ± 2.77
Total	125,944	1,723	13.68 ± 0.33	1,927	15.30 ± 0.35

TABLE 2

Distribution of occupational groups in 27 cities and towns with populations less than 100,000. Group 1, predominantly mental work; group 2, approximately equal amounts of mental and physical work; group 3, predominantly physical work; group 4, others.

GROUP	NO. OF FAMILIES	♂	♀	% OF POPULATION
1	1,914	7,176	7,643	15.43
2	2,527	9,095	9,408	19.26
3	7,755	31,856	28,317	62.65
4	420	1,245	1,314	2.66
Total	12,616	49,372	46,682	100.00

Data on the sample of 27 localities, based on 12,616 families are given in tables 2 and 3. These families were classified according to the father's occupation into four groups, defined in table 2. Table 2 lists the relative frequencies of the four groups including the number of males and females in each. In table 3, birth and death rates are shown for each of the occupational groups. Apart from the very small group (4), the death rates are rather similar varying from 13.1 to 14.5. The birth rates too, are similar among themselves—again omitting group (4). They lie between 19.4 and 20.8. They thus exceed the death rates in each of the three main occupational groups. This excess is smallest for the group

with mostly mental work, being 5.8. For the other two groups it is 7.1 and 6.3 respectively. The trend toward a differential reproductivity of different occupational groups obviously is not striking.

TABLE 3

Birth and death rates in four occupational groups in 27 cities and towns with populations less than 100,000.

GROUP (see Table 2)	BIRTHS ♂	BIRTHS ♀	BIRTH RATES PER 1000	DEATHS ♂	DEATHS ♀	DEATH RATES PER 1000
1	161	127	19.43 ± 1.13	91	111	13.63 ± 0.95
2	189	185	20.21 ± 1.03	132	111	13.13 ± 0.84
3	673	580	20.82 ± 0.58	515	358	14.51 ± 0.49
4	18	21	15.24 ± 2.42	27	15	16.41 ± 2.51
Total	1,041	913	20.34 ± 0.46	765	595	14.16 ± 0.38

TABLE 4

Sex-ratios at birth

AREAS	♂	♀	SEX-RATIO	% MASCULINITY	χ^2	P
Seoul	688	597	115.25	53.62 ± 1.39	6.44	0.01
Cheju	186	171	108.77	52.10 ± 2.64	0.63	0.4
Ulnung	42	39	107.69	51.86 ± 5.55	0.11	0.7
Total	916	807	113.50	53.16 ± 1.20	6.89	0.01

The birth and death rates reported here cannot be fully compared with those from general census data. This is so because our populations were mostly ascertained from school children, a method which leads to a distribution of ages in the population, which is different from that of populations ascertained completely.

The Sex Ratio at Birth

The sex ratio at birth, *i. e.*, the secondary sex ratio varies in different parts of the world (Ciocco, 1938). Nearly always an excess of males is apparent. In most Caucasian populations the ratio of male to female births lies between 104 : 100 and 106 : 100. For Korea the unusually high ratio of 113 : 100 has been reported. On the whole, our data agree with the earlier findings of a high secondary sex ratio (tables 4, 5). In Seoul, the ratio was 115 : 100 based on 1,285 births. On Cheju and Ulnung

Islands, it was 108.8:100 and 107:100 respectively based on smaller samples. The 1,954 births in the 27 localities again gave a very high ratio, namely 114:100. The combined data give a ratio of 113.78:100.

The cause of this high sex ratio is unknown. It is believed to be close to the true secondary sex ratio and not to be influenced to a significant degree by underreporting of female births.

There are considerable variations in the sex ratio between the different occupational groups. No clear trend can be observed. While the very high ratio of 126.8:100 in the group with mainly mental work finds its counterpart in some data on Western upper socio-economic groups, the low ratio of 102.2:100 for the mental and physical work group as compared to the higher ratio of 116:100 for the mainly physically occupied group can only be registered without any comment.

TABLE 5

Sex-ratios at birth

GROUP (See Table 2)	SEX RATIO	% MASCULINITY	χ^2	P
1	126.77	55.90 ± 2.93	4.01	0.04
2	102.16	50.53 ± 2.59	0.04	0.8
3	116.03	53.71 ± 1.41	6.90	0.01
4	85.71	46.16 ± 7.98	0.23	0.6
Total	114.02	53.27 ± 1.13	8.38	<0.01

Twins

The only Mongoloid population for which careful data on the frequencies and types of twins are available is that of Japan (Komai and Fukuoka, 1936; Inouye, 1957). In that country the frequencies of twin births are approximately 0.6–0.7% of all births. Identical twin births account for nearly two-thirds of the total twin births. These data are in contrast to those of Caucasoid populations in which the frequencies of twin birth are greater than 1% but in which the proportion of identical twin births is only approximately one-third of the total.

Our data from Korea do not refer to twin births but rather to twin pairs among the sibs of the school children who filled out the questionnaires, or to twin pairs reported from Cheju Island. In all cases the sexual composition of the twin pairs was ascertained. This made possible

the application of Weinberg's differential method for determination of the proportion of identical to non-identical pairs. All populations examined were similar in suggesting that close to two-thirds of the twin pairs were monozygotic in origin (table 6). The Korean populations thus resemble closely those of Japan in their proportions of mono- to dizygotic twin pairs.

TABLE 6

The composition of twin pairs

AREAS	NUMBER OF TWIN PAIRS	NUMBER AND RATIOS OF SEXUAL COMPOSITION ♂ ♂	♂ ♀	♀ ♀	NUMBER OF IDENTICAL TWIN PAIRS	NUMBER OF FRATERNAL TWIN PAIRS
Seoul	175	80	28	67	119	56
		2.86	1.00	2.39		
Cheju	30	16	5	9	20	10
		3.20	1.00	1.80		
27 localities	113	55	20	38	73	40
		2.75	1.00	1.90		
Total	318	151	53	114	212	106
		2.85	1.00	2.15		

The sex ratio of the combined twin pairs, 126.4 : 100, is even higher than that of the secondary sex ratio in the general Korean population as reported above. Specifically, the sex ratio of twins was 116 : 100 in 175 pairs from Seoul, 160.9 : 100 in the 30 pairs in Cheju and 132.6 : 100 in the 113 pairs from the 27 localities.

Consanguinity

It was expected that consanguineous marriages would be rare in Korea since they are prohibited in Confucianism. Our data are interesting in that they show a high frequency of first cousin marriages in the three main samples of Korean populations but also significant differences among them (table 7). During the three year period 1953-1956, no less than 7.8% of all marriages in Seoul were between first cousins and 5.9% in Cheju were of this type. In the 27 localities only 1.8% of such marriages occurred. These data are more similar to rates of consanguinity in Japan than in most Western populations.

The high frequencies of cousin marriages in Seoul and Cheju as compared to the sample from 27 other localities deserve some comment.

In Seoul two factors were involved in the high frequency. For one, the population of this city has experienced the greatest influence of Western thought and thus is inclined to deviate from Confucian prescriptions. For another, housing shortages have forced many related families to live under the same roof, leading to a tendency toward marriages between relatives. In Cheju a reason for the high frequency of cousin marriages is relative isolation of this island. On the other hand, the sample of 27 localities included rural areas in which the conservative prohibition of cousin marriage was more closely obeyed. For Seoul and Cheju it is possible to present data on the frequencies of the four possible subdivisions of first cousin marriages (table 8). It

TABLE 7

The frequencies of cousin marriages

AREA	NO. OF MARRIAGES	NO. OF COUSIN MARRIAGES	%
Seoul	474	37	7.81
Cheju	285	17	5.96
27 localities	605	11	1.82
Total	1,364	65	4.76

TABLE 8

Types of cousin marriages

WIFE'S RELATION TO HUSBAND	SEOUL	JEJU	TOTAL
Father's Brother's Daughter	5	3	8
Father's Sister's Daughter	5	2	7
Mother's Brother's Daughter	12	8	20
Mother's Sister's Daughter	15	4	19
Total	37	17	54

can be seen that marriages of cousins who are related through the father of the husband are less than one-half as frequent as those where the relation is through the mother of the husband. Very similar deviations from randomness of the four types of cousin marriages have been described for large samples from Austria and Japan (see Morton, 1955) but not for a group of smaller—though combined, still considerable—samples from different Western populations (Macklin, 1952). The causes underlying the nonrandomness among the Korean cousin marriages have not been studied.

SUMMARY

On the basis of questionnaires given to 18,227 middle and high school students in various localities in Korea and of answers obtained personally by one of the authors, vital statistic data were obtained on birth and death rates, the secondary sex-ratio, the number and sexual composition of twin pairs and the frequencies and types of first cousin marriages.

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THE SUN-TANNING POTENTIAL OF HUMAN SKIN

BY MARJORIE M. C. LEE AND GABRIEL W. LASKER
Department of Anatomy, Wayne State University, Detroit

INTRODUCTION

COLOR of the skin has been used as one of the most important criteria of race. Skin color is an inherited character, although the exact mode of inheritance is still not clearly known. Nevertheless, the color of the skin can also be influenced by various pathological conditions and environmental factors: adrenocortical deficiency and changes in the condition of the blood, such as anemia, cyanosis, jaundice, etc., and exposure to ultraviolet rays. Ultraviolet irradiation from the sun is by far the most common and important factor. It is our purpose to investigate the extent to which this environmental factor, *i. e.*, sunlight, can influence the skin color. What is the point of saturation beyond which no further darkening of the skin can take place with further ultraviolet exposure? How does the saturation point differ in people of different original color? And do members of the same racial groups respond similarly to ultraviolet irradiation? We have subjected circumscribed areas of skin of a number of individuals to ultraviolet irradiation under controlled conditions. Records of the amount of light reflected from the skin before and after this treatment may shed some light on each of these questions.

SUBJECTS AND METHODS

Fourteen adults, 22 to 66 years of age, both male and female, participated as volunteers. Eight of them are Whites, three Monogoloids and three American Negroes.

As an index of skin color we measured the reflection, from an area of skin, of light of several wave lengths. For this we used a portable photoelectric reflection meter (Photovolt Corporation, model 610. See Lasker, 1954a, 1954b and Garn, 1956). As will be seen in a diagram of the search unit (figure 1) the incident light is transmitted through a lens, then through a colored glass filter and then through a circular aperture in the measuring photocell. The distance to the skin and back to the photocell and the area of skin studied are constant because the search unit has a small round aperture which is directly in contact with the surface to be studied. As may be seen in the illustration, the incident

light strikes the skin surface at a right angle but is viewed at an average angular range of about 45°. Three glass filters were used: red, green and blue.[1]

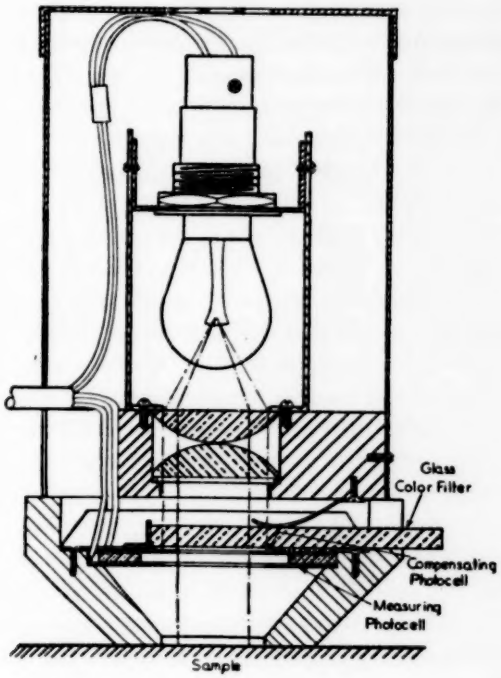

FIG 1. SEARCH UNIT OF THE PHOTOELECTRIC REFLECTION METER.

The reflection meter was standardized before each measurement against a white enamel standard which had previously been calibrated in terms of a newly prepared surface of magnesium oxide. We therefore have been able to report our results in terms of the absolute reflectance scale in which magnesium oxide is assumed to represent 100%.

[1] The peak transmission values of the filters are 6500, 5250 and 4200 Å for the red, green and blue filters respectively. The spectral band isolated by each filter is approximately 800 Å wide. The filter curves multiplied by the emission curve of the light source give peak values shifted somewhat in the direction of longer wavelength values, but not by more than 100 to 120 Å. Furthermore this shift is counteracted at the red part of the spectrum by the opposite slant of the spectral response curve of the photocell. In other words the measurements are actually carried out at 6500, 5350 and 4300 Å.

In order to compare, in a preliminary way, the response of a few individuals of different racial origins to the process of sun-tanning, we selected an ordinary mercury-vapor sunlight lamp, type RS, produced by the General Electric Company. Although close control of the physical conditions might make the use of narrow-band sources of radiant energy desirable, our emphasis is on the biological effects. Our needs are, therefore, met to the extent that the conditions of irradiation were constant from one time to another and from one individual to another, and that the spectral energy was roughly comparable, in capacity to produce pigment, to that of sunlight.[2]

The site of the body that we chose for the experiment is over the lower part of the back. It has a large flat surface, well protected from exposure to sun (at least in Detroit during March and April when our study was under way); it lacks the uneven spotty pigmentation which sometimes occurs over the upper part of the back and shoulders; it is easily accessible, and one side can conveniently be used for irradiation and the opposite side as control. In three cases among the males there was some body hair over the lower back; this was shaved off.

During irradiation, the back of the subject was protected by an oil-cloth jacket with a round hole on the right side, the only spot to be exposed to the irradiation. The center of the hole was 2½ inches (6 cm) to the right of the midline and 14 inches (36 cm) below the base of the neck. Each subject was exposed to the sunlamp once a day, except for a few days missed at weekends or when there seemed to be a risk of burning the skin. Light reflectance from the spot was measured before each exposure. Readings were also taken on the control side at the same time. While measuring the skin reflectance, the search unit was placed quite gently on the skin, as firm pressure produces a bulging of the skin and yields an incorrect value of reflectance.

The dosage of the ultraviolet irradiation is directly proportional to the exposure time, and inversely proportional to the square of the distance from the lamp to the skin. Each subject first received an empirical dose to produce a minimal perceptible erythema. The same dosage was continued for three or four days; a period which allowed the exposed skin to develop resistance to the ultraviolet rays. The dosage

[2] The spectral energy distribution of the RS sunlamp is approximately .01 watts between 2600 and 2800 Å, 1.70 watts between 2800 and 3200 Å, 3.40 watts between 3200 and 3800 Å and 7.60 watts in the range of visible light. The chief erythema-producing wavelengths are 2500 Å and 2967 Å while the most effective pigment-producing wavelengths are greater than 3200 Å (Koller, 1952).

was then increased slightly (usually by 50%) until the skin reached minimal reflectance and did not become any less reflective despite continued daily ultraviolet irradiation. In the first two cases, we continued the irradiation for 7 additional days without any lower reading in skin reflectance being recorded, even though in the last three days the dosage was increased to 100 or 150% more than the initial dose. Based on the experience gained with the first two cases, the rest of the cases were continued with increased dosages of exposure for only three or 4 days after the reflectance became constant.

FINDINGS

The skin reflectance readings of the control side provide a measure of reliability and reproducibility of the readings. There are 155 such readings for each of the three filters. The averages of the standard deviations for the 14 control sides are small, ± 0.57, ± 0.75 and $\pm 0.62\%$ for the red, green and blue filters respectively. The standard deviations are quite similar in lighter and darker individuals.

In order to compare the amount of irradiation used in different cases, the ultraviolet irradiation in this experiment is given in terms of arbitrary units. One unit is the irradiation received at a distance of 18 inches (46 cm) from the lamp in three minutes. Three of the White people needed only one unit to produce a perceptible erythemal effect, the other 5 Whites each needed 2.25 units. The three Mongoloids needed 2.25 units each, and the three Negroes needed 4 units each to produce perceptible erythema.

On the day following the initial erythema, there is a decrease in skin reflectance with the green and blue filters; no change can be observed with the red filter. The red filter shows no drop until the third or fourth day, when real tanning of the skin takes place. The exposed skin usually reached its minimum reflectance after 7 to 9 days of ultraviolet irradiation.

The decrease in reflectance of the skin in response to ultraviolet irradiation is variable even among people of the same race. Of two persons with similar initial reflectance, one may change several times as much as the other. The decrease in reflectance noted with the three different filters is shown in table 1. The Negro skins decrease little in reflectance, but since their original readings are low, their relative decrease is still considerable. Mongoloid skins decrease considerably in reflectance both absolutely and relatively. In most White skins the

decrease is small, especially with the red filter. Two White individuals with black hair (one of Italian, the other of Spanish-Hungarian origin), show quite different reactions from the blond and brown-haired Whites. These two show a marked drop in skin reflectance with all three filters—

TABLE 1

Reflectance of the skin before and after ultraviolet irradiation.

			REFLECTANCE					
			RED FILTER		GREEN FILTER		BLUE FILTER	
GROUP	SUBJECT	SEX	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
I	1	M	68.0	62.0	46.9	29.0	40.1	25.7
	2	M	66.3	64.2	45.3	34.4	38.4	27.8
	3	M	64.7	62.5	43.2	34.1	38.7	30.9
	4	M	62.0	57.8	41.3	26.1	33.8	21.6
	5	M	61.3	57.5	40.1	32.6	33.0	25.3
	6	M	60.0	54.3	36.3	25.4	28.8	20.5
II	7	M	61.8	44.4	41.7	19.3	33.9	15.7
	8	F	58.0	47.0	33.4	20.0	26.4	16.0
III	9	F	61.3	46.5	40.6	21.3	32.3	16.2
	10	M	55.2	48.1	27.2	20.8	21.6	16.2
	11	M	52.3	41.7	28.7	16.5	21.6	12.7
IV	12	M	41.5	28.4	17.2	10.7	14.1	9.0
	13	M	36.2	28.5	13.1	9.9	11.3	8.5
	14	M	27.4	19.5	10.6	7.2	9.1	6.7

I. Blond and brown-haired Whites; II. Black-haired Whites; III. Mongoloids; IV. American Negroes.

even more than the three Mongoloid subjects—although their reflectance values are higher and their skin color apparently lighter than that of two of the three Mongoloids.

A comparison of the changes in reflectance with different filters may help to distinguish increased melain from erythema. Light transmitted through the blue and green filters is absorbed by hemoglobin as well as by melanin, but light transmitted through the red filter is reflected from blood pigments. The difference between the readings with blue and red filters appears to increase especially in the 6 light-haired White individuals but does not occur among the three Negroes, in whom either there is little tendency to erythema or it is masked by melanin. Only one

individual, the darkest Negro, shows a greater relative drop in reflectance with the red than with the blue filter.

DISCUSSION

Normal color of living human skin comes from various sources: melanin, melanoid, carotene, oxyhemoglobin, and reduced hemoglobin. The melanin in the epidermis and the hemoglobin in the superficial

TABLE 2

Decrease in reflectance of the skin after ultraviolet irradiation.

			ABSOLUTE DECREASE IN REFLECTANCE			DECREASE AS PER CENT OF INITIAL REFLECTANCE		
GROUP	SUBJECT	SEX	RED	GREEN	BLUE	RED	GREEN	BLUE
I	1	M	6.0	17.9	14.4	8.8	38.2	36.0
	2	M	2.1	10.9	10.6	3.2	24.1	27.6
	3	M	2.2	9.1	7.8	3.4	21.1	20.2
	4	M	4.2	15.2	12.2	6.8	36.8	36.1
	5	M	3.8	7.5	7.7	6.2	18.7	23.3
	6	M	5.7	10.9	8.3	9.5	30.0	28.8
II	7	M	17.4	22.4	18.2	28.2	53.7	53.7
	8	F	11.0	13.4	10.4	19.0	40.1	39.4
III	9	F	14.8	19.3	16.1	24.1	47.5	49.8
	10	M	7.1	6.4	5.4	12.9	23.5	25.0
	11	M	10.6	12.2	8.9	20.3	42.5	41.2
IV	12	M	13.1	6.5	5.1	31.6	37.8	36.2
	13	M	7.7	3.2	2.8	21.3	24.4	24.8
	14	M	7.9	3.4	2.4	28.8	32.1	26.4

I. Blond and brown-haired Whites; II. Black-haired Whites; III. Mongoloids; IV. American Negroes.

blood vessels of the dermis play the most important role in determining the skin color (Brunsting and Sheard, 1929). Edwards and Duntley (1939a) have analyzed the human skin color with a Hardy spectrophotometer and confirm the histological finding that the variation in quantity of melanin in epidermis is responsible for the difference in racial coloration. They also state that when there is much melanin it prevents the superficial blood from attaining visibility.

In sun-tanning, two main factors affect the darkening of the skin: first, increased hemoglobin (erythema); second, increased melanin. We

found that in the first two days, the initial erythema stage, there is a decrease in reflectance with the green and the blue filters, but no change with the red. Because hemoglobin in the skin does not absorb the light rays transmitted by the red filter, an increase in hemoglobin in the erythemal stage does not cause any appreciable change in reading with the red filter. Readings with the red filter can therefore be considered as an index of melanin. The rays which come through the blue and green filters can be absorbed by hemoglobin as well as melanin, so the readings with either of these two filters represent the summation of the absorption by melanin and of the effects of changed vascularization. The light-haired Whites and the Negroes show relatively little increase in absorption with the red filter; so there is apparently little increase in the relative melanin content of the skin after ultraviolet irradiation. In the two black-haired Whites and the three Mongoloids the relative increase in melanin appears to be much greater. The green and the blue filters show considerable change in absorption in all 8 Whites and all three Mongoloids, suggesting that there is a large degree of erythema affecting the darkening of skin color at the end of the course of ultraviolet irradiation. This is especially true in the light-haired Whites. The skin color of the Negroes changes very little in absorption with either green or blue filters, so the erythema effect is either weak or obscured by the layer of heavy melanin in the epidermis.

On the basis of histological findings, Keller (1928) and Miescher (1930) say that in the first stage of sun-tan, melanin migrates from the basal layers of the epidermis upwards, and that there is no actual increase in amount. Jansen (1953), using reflection spectrophotometry, shows that there is an upward migration of melanin on the eighth day after a single dose of ultraviolet rays. The darkening of the skin caused by melanin concentration is not strictly a surface phenomenon. Reflectance is not a function of, nor closely comparable with transmission of light. Therefore, it cannot *a priori* be assumed that absorption is proportional to the logarithm of the density of melanin. In the absence of empirical data bearing on the question we hesitate to estimate the extent of change in melanin from the degree of change in reflectance.

Edwards and Duntley (1939b) gave a single large exposure to sunlight to a single individual and found that the maximal increase in melanin was not reached until the nineteenth day. In our experiment with repeated small exposures, the maximal darkening was usually achieved between the seventh and the ninth day.

Hausser and Vahle (according to Kuppenheim and Heer, 1951-52) found that it required about 10 times as much ultraviolet energy to produce the same erythema in a Negro subject than it did in Whites. We found that, on the average, it takes 2.2 times as much irradiation in Negroes and 1.3 times as much in Mongoloids to produce the same minimal perceptible erythema as in Whites.

CONCLUSIONS

Using a red filter, so that the effect of erythema is minimal and that of tanning maximal, the amount of light reflected following repeated ultraviolet irradiation may be reduced by from 3 to 31%. Even in two individuals with similar initial reflectance or of similar racial background, the change in one may be several times as great as that in the other. The relative decrease in reflectance with a red filter is smallest in blond and brown-haired Whites, and greatest in Negroes. However, the range in Monogoloids and black-haired Whites overlaps that of the Negroes. Use of green and blue filters records the effects of erythema as well as melanin. Except for the darkest Negro individual all subjects showed relatively more change in reflectance measured with the blue than with the red filter. The results of this experiment confirm that there are wide individual differences in suntanning. The limited observations do not reveal any specifically racial characteristic in this respect, however.

ACKNOWLEDGMENT

We cordially appreciate the zeal of our volunteers in participating in this experiment. Gratitude is also extended to Dr. J. J. Groen, of the Department of Industrial Medicine, Wayne State University, for answering some of the authors' questions about spectral physics.

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BONE STRENGTH–ITS RELATIONSHIP TO X-RAY-DETERMINED ASH CONTENT[1]

BY GEORGE P. VOSE AND ALBERT L. KUBALA, JR.

The Nelda Childers Stark Laboratory for Human Nutrition Research
Texas Woman's University
Denton, Texas

THE measurement of bone strength has long been a fascinating research area for biologists and anatomists. Although weighing only one-third as much, bone has the tensile strength of cast iron under static loading; and its elasticity permits it to absorb impact loads several times higher. There have been relatively few studies on the strength of human bone, although the number of investigations has increased in recent years. Evans and Lebow (1951, 1952) measured the tensile strength of compact human bone and found significant strength variations among samples from different parts of the same bone. Carothers, Smith, and Calabrisi (1949) tested the effects of drying and embalming upon the strength of compact bone. In the investigation which is the subject of the present report we have produced transverse fractures through bending of the femur by applying force to the middle of the shaft perpendicular to its long axis, and have related breaking stress obtained by this method to bone ash content.

In an earlier report (Vose, 1958b) a new analytical procedure, employing a low intensity polychromatic x-ray beam, was applied specifically to the determination of the organic and inorganic contents of dried, ground bone. With 1.0- to 1.5-gram samples the concentration of the two fractions is related exponentially to the per cent x-ray transmittance, thus providing an expedient and accurate means for measuring mineral content without the need for ashing the bone. This method has been used to determine the ash content of the bones used in this study.

The factors which affect the strength of bone still are not clearly understood, but any changes in the quality or quantity of either the organic or inorganic fractions may result in changes in bone strength. Wier, Bell, and Chambers (1949), working with rats that had been

[1] This work was supported in part by Grant No. A-2641 from the National Institute of Arthritis and Metabolic Diseases, the National Institutes of Health, U. S. Public Health Service.

maintained on rachitogenic diets, found a positive correlation between breaking stress and per cent ash content in the femur. Hence bone strength in animals has been found to be measurably related to its composition.

METHODS

Twenty-five human femurs were obtained for breaking stress and x-ray-determined composition measurements. All but two of the femurs had been removed from embalmed white and Negro cadavers of both sexes between the ages of 30 and 70 years. The remaining pair was taken from a twelve-year old white female. All the bones were cleaned and the periosteum removed. Twenty-one femurs were dried at room temperature for 30 days before the breaking tests, and four were soaked in Ringer's Solution and tested wet.

Determination of Bone Breaking Stress

The femur was selected for strength and ash analysis because it is the largest bone in the body, and because its approximate elliptical shape make the determination of its moment of inertia relatively simple. Admittedly, the variations from the proportions of a true ellipse among individual bones will alter the apparent breaking stress to a slight degree.

To obtain the breaking load, each femur was supported horizontally and force was applied downward upon the center of the posterior surface of the shaft by use of a specially constructed 8000-pound capacity hydraulic testing device. The principal components of the device were (1) a rack constructed from ¼-inch steel which was approximately 50 inches high, 30 inches wide, and 10 inches deep. Suspended within the rack was (2) a hardwood cabinet with a hinged Plexiglas window through which the bone could be observed while force was being applied, and (3) mounted atop the rack was a Black Hawk hydraulic Porto-Power pump which applied force downward through a steel plunger of adjustable length. Two pressure gauges were used interchangeably in the hydraulic system. A 1000-pound capacity gauge was used during the greatest number of tests, but several of the bones required a 2000-pound gauge in order to obtain the breaking load. Force was applied manually at the rate of about 500 pounds a minute. The strain gauge was an integral part of the hydraulic plunger which indicated the maximum amount of bending at the instant of fracture. The reading was retained on the gauge until the scale was reset by the operator.

Each bone was supported within the cabinet and force was applied

tangent to the axis of natural curvature which tended to stabilize the bone upon its end supports. The supports were constructed from oak blocks which were hollowed out to approximate closely the dimensions of the distal and proximal anterior surfaces. The supports were adjusted to the effective span for each femur as measured from a point just below the lesser trochanter to a point immediately above the adductor tubercle. In this manner the strength of the compact bone of only the femur shaft was obtained, and the structural weakness of the extremities was avoided. Next, the hydraulic plunger was adjusted to the surface of the bone and the attached strain gauge adjusted to zero. Force was then applied at this loading site until fracture by bending occurred, and the breaking load in pounds (subsequently converted into kilograms) and the deformation in millimeters were read directly from the corresponding gauges.

The breaking load, which may vary between 150 and 600 kilograms in embalmed normal femurs, is a measure of the strength of the bone as a whole witout regard for bone size. In order to convert the breaking load into breaking stress or force per unit area, certain dimensions of the bone had to be determined as indicated in Figure 1(A). The strength of the bony material was calculated by a method similar to that used by Wier, Bell, and Chambers (1949) according to the formula

$$S = \frac{W l D}{8\left[\frac{\pi}{64}\left(BD^3 - bd^3\right)\right]}$$

Where

S = Breaking stress by bending
W = Breaking load
l = Span of femur shaft
B = External width at stress point
b = Internal width at stress point
D = External depth at stress point
d = Internal depth at stress point.

X-ray Determination of Ash Content

The total femur length between the proximal border of the greater trochanter and the distal border of the medial condyle was measured and divided into three sections of equal length. As shown in Figure 1(B) a two-centimeter section was removed at the midpoint of each one-third. All of the soft material within the medullary cavity was removed. The remaining compact bone was broken into small pieces

and then pulverized in a Waring Blender, and each sample obtained in this manner was dried to constant weight in an Ohaus Moisture Determination Balance.

In making the x-ray measurements, a General Electric KX-8 Generating Unit was used with an HRT-2 rotating tungsten anode tube.

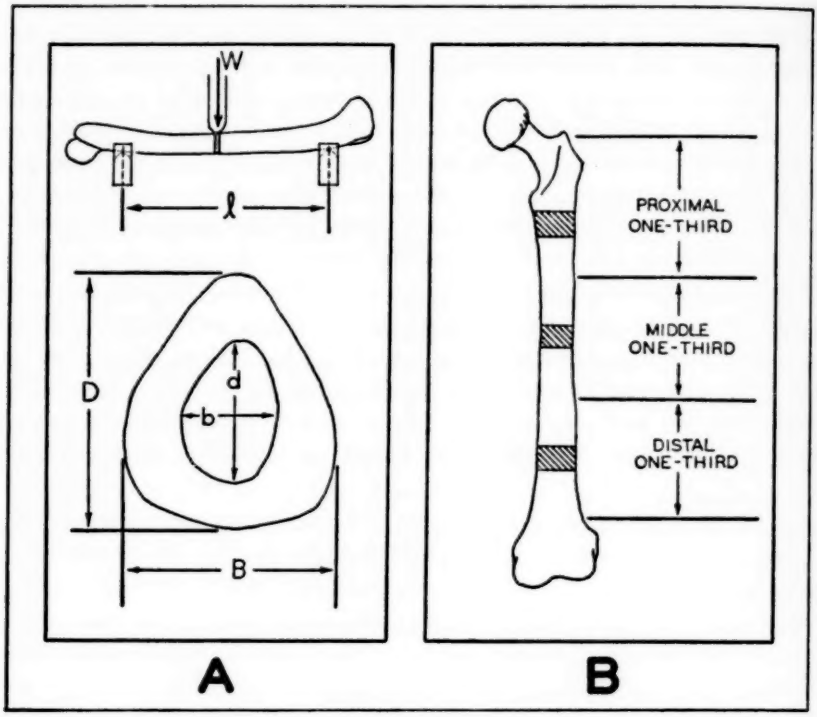

FIG. 1. (A) CROSS-SECTIONAL AND LONGITUDINAL VIEWS OF SUPPORTED FEMUR INDICATING DIMENSIONS USED IN THE BREAKING STRESS COMPUTATIONS.

(B) SITES FROM WHICH SAMPLES WERE REMOVED (CROSS HATCHED) FROM EACH ONE-THIRD OF THE FEMUR SHAFT.

As in previous work (Vose, 1958b) all filtration was removed from the tube housing so that the relatively soft beam produced at 40 kvp was utilized. A Model 287 Victoreen Minometer with a 0 to 0.1-r chamber was used to measure the transmitted x-radiation. Samples of 1.5 grams of dried, pulverized bone were placed in a cylindrical sample chamber which compressed each sample of bone material into a small volume. The chamber was designed to fit into a steel cylinder mounted above the

x-ray tube so that the beam was conducted vertically through the cylinder and sample chamber, and into the ionization chamber. The per cent x-ray transmittance for each sample was obtained in two steps, first by measuring the transmittance through the 1.5-gram sample, second by measuring the transmittance through the empty sample chamber. The per cent transmittance was obtained by the usual formula, $100\,I/I_0$. The exponential relationship between the x-ray transmittance and the per cent ash content for 1.0- and 1.5-gram samples is shown in Figure 2.

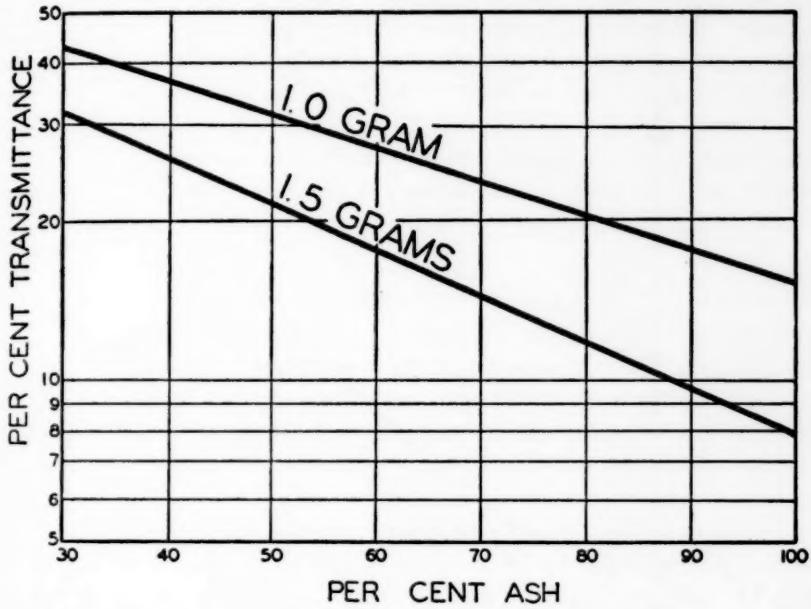

FIG. 2. RELATIONSHIP BETWEEN PER CENT ASH AND PER CENT TRANSMITTANCE IN 1.0- AND 1.5-GRAM SAMPLES OF DRIED, GROUND BONE TISSUE.

RESULTS

The results of plotting x-ray-determined ash content vs breaking stress of the femur revealed that the two factors were related in an exponential manner. A plot of breaking stress vs ash content is shown in Figure 3. The figure shows that there is an obvious relationship between the two variates, and a statistical treatment to determine what kind of mathematical curve best describes the observed relationship has been made.

First, a straight line was fitted by least squares, and a product

moment correlation coefficient of .94 was obtained. This coefficient is significant well beyond the .001 level. It was found that a second degree polynomial yielded somewhat smaller errors of prediction, but a rational defense of a parabolic relationship with this type of data seemed untenable, so an exponential curve was tried. Because of the extreme diffi-

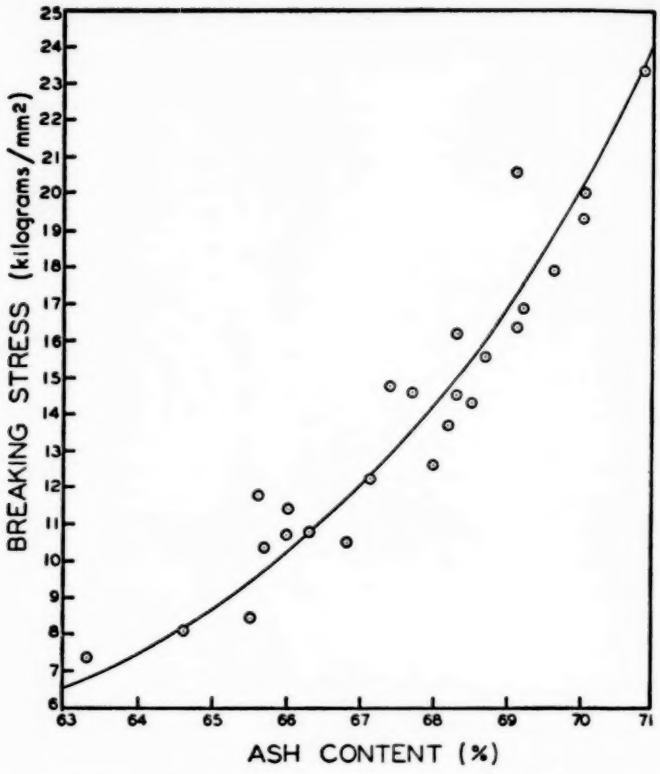

FIG. 3. EXPONENTIAL RELATIONSHIP BETWEEN BREAKING STRESS IN KG/MM² AND CORTICAL ASH CONTENT OF THE FEMUR.

culties in fitting exponentials by the method of least squares, the curve was determined in a different manner. Three points were chosen on the plot through which it seemed likely that the curve should pass, and these points were employed to obtain three equations of the form $y = ae^{bx} + c$, where x, the independent variable, is per cent ash content. The three constants were then determined and the equation obtained was $y = 1.304e^{\cdot 202x} + 2.210$. This curve is the one reproduced in Figure 3.

The exponential curve yielded smaller errors of prediction than the rectilinear curve, but the prediction was not significantly better. It might be argued that the principle of parsimony would favor the acceptance of a simpler, or rectilinear form of relationship, but one other important fact must be taken into consideration. Employing the line of best fit in this data, it would be predicted that a femur with a cortical ash content of 60.8% would have a breaking stress of zero. Since ash contents as low as 54% of the dry skeletal weight have been reported (Trotter and Peterson, 1955) the straight line determined from our data obviously cannot represent the true relationship between breaking stress and ash content. This factor, plus the fact that the exponential curve did fit the data somewhat better, seemed to warrant the postulation of an exponential form of relationship between the two variables.

No clearly defined correlation between strain per unit length and breaking stress was found. It is possible that a correlation might have been found had all of the bones been of the same degree of dryness.

DISCUSSION

In living bone, fracture may be caused by any of 5 types of straining —axial compression, axial tension, bending, shearing, and twisting. All of the foregoing loading conditions may result from either static or impact forces. Admittedly, bone fracture is more likely to occur through impact than under static loading conditions, but the latter can be measured with much higher precision. In addition, there is without question a relationship between impact and static yielding loads.

There are a number of inherent factors which complicate the determination of breaking stress by bending in bone. These are (1) both tensile and compressive forces are involved which are greatest on the convex (lower) and concave (upper) aspects respectively and decrease inwardly toward a neutral axis; and (2) the cross sectional area and shape varies along the shaft, and the walls are not of uniform thickness. Nevertheless, the breaking stresses by bending are related in a complex manner to the breaking stress caused by loading conditions which more commonly result in bone fracture. There are several factors which might affect the relationship between bone strength and ash content. Changes in the quality and quantity of bone mineral or collagen might result from such natural factors as age, sex, and race; and from such unnatural factors as the degree of dryness of the bone, and whether the bone is embalmed or unembalmed.

Evans and Lebow (1951) reported no consistent relationship between the age of the individual and bone strength, although some of the older literature is not in agreement with this (Rauber, 1876).

Differences in breaking stress accountable to sex are undoubtedly slight, although the breaking load is roughly related to bone size. Evans (1957) reported that the average breaking stress of samples from male femurs was only about 5% greater than similar samples from female femurs.

Although there is no known work in which the breaking stress of bones from Negroes and whites have been compared, Baker and Schraer (1958) reported slight differences in x-ray absorption coefficients among bones of equal weight from Negroes and whites.

Strength differences accountable to drying or embalming might cause fairly large errors. Evans and Lebow (1951) have reported that drying of bone samples from femurs of human cadavers increased their average tensile strength by about 30%, but reduced their percentage elongation under tension. Dempster and Liddicoat (1952) reported breaking stresses of fresh and dry bone samples which were in good agreement with the earlier findings of Evans and Lebow. In the study upon which this report was based, the right femurs of two cadavers were tested after being soaked in Ringer's Solution for three weeks, and the left femurs were tested after drying at 95° F. for three weeks. The wet bones were found to have breaking stresses by bending about 3% greater than those of the dry bones. This evidence suggests that drying at room temperature for reasonable lengths of time will not significantly affect breaking stress although higher drying temperatures undoubtedly will affect it. It was found that the cortex of three femurs dried at room temperature for 6 months still contained about 10 or 11% water. Since none of the bones in the study had been permitted to remain at room temperature for more than three weeks, the error accountable to the state of dryness appeared to be within 3%.

The influence of embalming upon the strength of compact bone was investigated by Calabrisi and Smith (1951) who used machined samples taken from various parts of femurs from embalmed dissecting room cadavers. Their measurements showed that embalming reduced the compressive strength of compact bone by about 13%.

It is obvious that the effect of certain postmortem alterations will affect bone strength in an abnormal manner. However, there is undoubtedly a relationship between the breaking stresses of dried, embalmed bones and their original breaking stresses within the host.

It would be extremely useful if bone strength could be predicted in the living human being. However, quantitative *in vivo* determinations of bone mineral concentration are difficult because of differential x-ray scattering by the bone matrix and the overlying soft tissue. In the case of bones having only thin coverings of soft tissue, such as the distal extremity of the femur, a method for direct quantitative measurement of the mineral content has been described by this laboratory by use of a collimated x-ray beam and a sensitive detection system (Vose, 1958a, 1959). Deeper coverings of soft tissue greatly complicate *in vivo* measurements of bone mineral concentration, and further work must be done before the scattering effect by soft tissue can be completely corrected. If this can be accomplished with sufficient accuracy, it will be possible to estimate bone strength *in vivo* since it is related in a known manner to the ratio of its organic and inorganic components.

SUMMARY

The breaking loads through bending for 25 dried, embalmed human femurs have been measured by use of an 8000-pound hydraulic testing machine. The breaking stresses were computed through application of dimensional factors of the individual bones. Next, a new analytical procedure employing a low intensity polychromatic x-ray beam was used to determine the ash content of samples removed from three sites in each femur, and the breaking stresses and average ash contents were correlated and found to be related by an exponential function. No clearly defined correlation between strain per unit length and breaking stress by bending was found.

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BIAS IN POLIOMYELITIS RATES BASED ON EXPOSED-TO-RISK FORMULAS

BY MONROE G. SIRKEN *
National Office of Vital Statistics
U. S. Public Health Service

and

T. N. E. GREVILLE
Office of the Quartermaster General
U. S. Department of the Army

INTRODUCTION

THE customary method of computing an annual rate of an event according to exposed-to-risk formulas is:

$$\frac{\text{Number of events in population}}{\text{Average size of population during year}} \tag{1}$$

It has been pointed out by Bradford Hill (1950) that in situations in which incidence rates of the event in question show marked seasonality and the population at risk also undergoes substantial reduction or increases in size during the observation period, this method of computation can give misleading results. This type of situation was recently encountered in the field of epidemiology. The problem involved measuring the effectiveness of the poliomyelitis vaccine based on the poliomyelitis incidence rates of vaccinated persons and unvaccinated persons in the United States during 1957. During that year, the population was participating heavily in the poliomyelitis vaccination program, and the marked seasonality of the disease is well known.

The problem can be illustrated by a somewhat extreme hypothetical example. Suppose that in a certain population deaths from a certain cause occur at the constant rate of 5 per million during the first half of a calendar year and at the constant rate of 10 per million during the

* Thanks are due to Dr. Carl C. Dauer of the National Office of Vital Statistics for encouragement to study this problem and to Dr. Lauri D. Thrupp, Miss Helen Forester and Dr. Jacob A. Brody of the Poliomyelitis Surveillance Unit of the Communicable Disease Center U. S. PHS, Atlanta, Georgia, for practical assistance in getting tabulations of the poliomyelitis cases.

second half, while the size of the population is 2 million during the first half and 1 million during the second. A simple calculation shows that the average annual death rate by formula (1) is $6\frac{2}{3}$ per million. Now consider another population in which the respective death rates are 4 and 8 per million and the corresponding populations are 1 million and 2 million. Calculation again gives an average rate of $6\frac{2}{3}$ per million, even though the death rate in each half of the year was lower than in the first example.

The bias resulting from the combination of seasonality of incidence rates with population fluctuations can be eliminated by computing a cohort rate—that is, the proportion of occurrence of the given event which would result in a closed cohort subject in every part of the year to the same risk of occurrence of the given event as the actual population under study. This is the same procedure that is used when a life table is constructed from the age-specific death rates observed in a population during a specified period.

In practice, such a cohort rate cannot be computed exactly because the population count is available only for a few dates during the year and the number of occurrences of the given event is available only for certain limited subdivisions of the year. In the subsequent section of this report, a computational procedure is outlined which provides upper and lower bounds on the cohort rate. In next to the last section, this procedure is applied to poliomyelitis data available for the United States in 1957. In the final section, the poliomyelitis rates and effectiveness of the vaccine are computed by formula (1) and compared with those computed by the suggested procedure.

PROCEDURE FOR COMPUTING RATES

The computational procedure has most relevance to situations for which estimates of the number of events are available for subdivisions (not necessarily of equal size) of the year, and estimates of the population at risk are available for each subdivisional period. The procedure involves (1) computing the rate of each subdivision of the year, and (2) adding the subdivisional rates to obtain the annual rate.[1]

The formula for computing the subdivisional rate is:

$$(2) \qquad \frac{\text{Number of events in the population during the subdivision of the year}}{\text{Size of population at a date during the subdivision of the year}}$$

[1] As shown in the Appendix, this applies when the annual rate is not large.

The mathematical theory derived in the appendix of this report states that the denominator of the rate is equal to the population size at some date during the subdivisional period. If an estimate of the population size at a single date during the period is available, it would be used for the denominator.

In the event that the minimum and maximum sizes of the population during the period are known, upper and lower bounds of the rate for that period may be derived. Substitution of the minimum population size in the denominator would give the upper bound and substitution of the maximum population size would give the lower bound of the subdivisional rate. The point estimate of the subdivisional rate would be obtained by use of a value of the population size in the denominator that is at a point (say midway) between the minimum and maximum population sizes.

The lower bound of the annual rate is equal to the sum of the lower bound rates for the subdivisional periods and the upper bound is equal to the sum of the upper bound rates for those subdivisional periods. The difference between the upper and lower bounds of a rate for a period of fixed length can not be increased and may be decreased by further subdivision. Thus, the reliability of the annual rate is in general improved by increasing the number of periods into which the year is subdivided. The detail of data available will usually place a limit on the number of subdivisions since information pertaining to the number of events occurring during the period and estimates of the population size would be needed for each period. On the other hand, if further subdivision of the year does not appreciably improve the accuracy of the annual rate, it would be inefficient to do so. From this viewpoint, the nature and extent of subdivision of the year becomes a matter for empirical investigation.

POLIOMYELITIS RATES AND VACCINE EFFECTIVENESS

The Salk poliomyelitis vaccine is administered in three doses. In 1957 medical authorities recommended that the second and third doses should be spaced about one month and seven months, respectively, after the first dose. In view of the short spacing interval between the first and second doses, poliomyelitis rates in this report are computed for the combined classes representing persons who received one or two inoculations rather than for each class separately.

The extent of participation of the population under 20 years of age in the poliomyelitis inoculation program at selected dates during 1957 is

shown in table 1. The estimates are based on data collected in two national household surveys—one conducted during the third week of August (Sirken and Brenner, 1959); the other conducted during the third week of November. The surveys were sponsored by the Public Health Service and conducted by the Bureau of the Census as supplements to the Current Population Survey. The Current Population Survey uses a probability sample design covering the non-institutionalized civilian population of the continental United States (Current Population Reports, 1958).

TABLE 1

Estimates of the poliomyelitis inoculation status of the U. S. population under 20 years at selected dates during 1957

DATE	POPULATION (IN 1000'S) BY NUMBER OF INOCULATIONS RECEIVED		
	NONE	1 OR 2	3 OR MORE
January 1, 1957	30,648	21,796	9,694
February 15, 1957	28,045	21,330	12,950
April 1, 1957	25,442	20,864	16,206
May 15, 1957	22,506	18,815	21,462
July 1, 1957	19,570	16,766	26,718
August 15, 1957	18,096	16,801	28,419
October 1, 1957	18,266	15,604	29,736
November 15, 1957	18,436	14,405	31,054
January 1, 1958	18,356	14,018	31,810

About the same number of persons were vaccinated and unvaccinated at the beginning of the calendar year but by the end of the year, the vaccinated population was about $2\frac{1}{2}$ times larger than the unvaccinated population. The increase in the vaccinated population was due entirely to the increase in the number of triply vaccinated persons since the number of persons with one or two inoculations declined steadily throughout the year.

The surveys provided estimates of the population's participation in the inoculation program as of the middle of the third and fourth quarters of 1957. Estimates of the inoculation status of the population at the beginning of the first, second and third quarters of 1957 were derived by retrojecting the experience of the cohort interviewed in August on the basis of the reported date of the last inoculation and assuming prescribed waiting periods between earlier inoculations. Estimates of the inoculation status of the population at midpoint of the first

and second quarter were obtained by linear interpolation. Estimates of inoculation participation at the beginning of the fourth quarter were obtained by linear interpolation between the two survey results. Estimates for the end of the fourth quarter were derived by projecting the intentions of the cohort interviewed in November. Finally, the retrojected estimates based on the August cohort and the projected estimates based on the November cohort were appropriately adjusted to reflect changes in the population size during 1957.

TABLE 2

Poliomyelitis cases reported by quarter of onset and inoculation status: U. S. population under 20 years, 1957 *

QUARTER OF ONSET	NUMBER OF INOCULATIONS RECEIVED		
	NONE	1 OR 2	3 OR MORE
Paralytic and Non-Paralytic Cases			
Total	1,823	1,044	745
1st quarter	190	70	29
2nd quarter	380	183	134
3rd quarter	1,021	703	529
4th quarter	232	88	53
Paralytic Cases			
Total	1,120	382	192
1st quarter	133	34	14
2nd quarter	224	64	22
3rd quarter	571	229	117
4th quarter	192	55	39

* Data in this table were supplied by the Poliomyelitis Surveillance Unit; Communicable Disease Center U. S. PHS; Atlanta, Georgia.

The survey estimates of the inoculation status of the population for August 15 and November 15 appear to be highly reliable. Relative sampling errors of the population estimates are less than 2% (1 standard deviation) and according to check interviews in a resurvey of a subsample of households, response bias was not a significant factor. The retrojected estimates of the population with one or two inoculations may be slightly too large because the average spacing between successive inoculations appears to have been somewhat longer than that assumed. For example, January and February 1956 were retrojected dates of first and

second inoculations of persons who reported getting their third inoculation during August 1957 assuming that the second and third inoculations were administered six and seven months, respectively, before the

TABLE 3

Bounds on the annual poliomyelitis rate according to the manner of subdividing the year by inoculation status of the population: United States population under 20 years, 1957

SUBDIVISIONS USED TO COMPUTE RATE	ANNUAL RATE (PER 1,000,000) LOWER BOUND	UPPER BOUND	RANGE
Paralytic and Nonparalytic Cases			
No inoculations			
Without subdivision	59.5	100.7	41.2
2 semi-annual periods	82.6	98.4	15.8
4 quarterly periods	85.9	96.0	9.1
One or two inoculations			
Without subdivision	47.9	74.5	26.6
2 semi-annual periods	58.8	71.5	12.7
4 quarterly periods	59.6	65.6	6.0
3 or more inoculations			
Without subdivision	23.4	76.8	53.4
2 semi-annual periods	24.4	38.6	14.2
4 quarterly periods	26.3	32.8	6.3
Paralytic Cases			
No inoculations			
Without subdivision	36.5	61.9	25.4
2 semi-annual periods	50.6	60.4	9.8
4 quarterly periods	52.7	58.7	6.0
One or two inoculations			
Without subdivision	17.5	27.3	9.8
2 semi-annual periods	21.4	26.1	4.7
4 quarterly periods	21.8	24.0	2.2
3 or more inoculations			
Without subdivision	6.0	19.8	13.8
2 semi-annual periods	6.2	9.6	3.4
4 quarterly periods	6.8	8.5	1.7

third inoculation. In actuality, however, these persons were more likely to have obtained their first and second inoculations prior to than after these dates. The projected values of the uninoculated population may be slightly overstated because usually these persons tended not to get inoculated as soon as the expected dates which they reported in the survey.

The number of reported cases of poliomyelitis under 20 years of age in the United States during 1957 by quarter of onset of the disease and number of inoculations received prior to the onset of the disease are shown in table 2. It will be noted that poliomyelitis is a seasonal disease with most of the cases occurring during the third quarter of the year. The data are shown separately for confirmed paralytic polio cases.

Applying the procedure for computing rates outlined in the previous section to the data contained in tables 1 and 2, upper and lower bounds of the poliomyelitis rates were derived separately for persons with no inoculations, one or more inoculations, and three or more inoculations. The upper and lower bounds were computed under three sets of conditions with regard to subdividing the year: (a) without subdivisions, (b) two semi-annual periods, and (c) four quarterly periods. The results per-

TABLE 4

Bounds on the estimates of the vaccine effectiveness by number of inoculations received: United States population under 20 years, 1957

INOCULATION STATUS	PERCENT EFFECTIVENESS OF VACCINE		
	LOWER BOUND	UPPER BOUND	RANGE
Paralytic and Nonparalytic Cases			
One or two inoculations	23.6	38.0	14.4
Three or more inoculations	61.8	72.6	10.8
Paralytic Cases			
One or two inoculations	54.4	62.9	8.5
Three or more inoculations	83.9	88.4	4.5

taining to rates for combined paralytic and nonparalytic cases and for paralytic cases only are presented in table 3. The figures show substantial reductions in the range between the upper and lower bound with increases in number of subdivisions used to compute the rate.

The effectiveness of the poliomyelitis vaccine is measured by percentage reduction in the poliomyelitis rate for persons with inoculations as compared to the rate for persons without inoculations. Assuming that the year is subdivided into four quarters for purposes of computing the rate, table 4 contains upper and lower bounds on estimates of the vaccine's effectiveness. Greater precision in the estimate of vaccine effectiveness would have been obtained if finer subdivisions of the year had been used in calculating the poliomyelitis rates.

COMPARISON OF THE METHODS FOR COMPUTING RATES

In the second section of this report, it was suggested that a point estimate of the rate for each subdivision would be obtained by setting the denominator of formula (2) equal to the average of the maximum and minimum population sizes during the quarter. On this basis annual rates were computed based on 4 quarterly subdivisions of the year. Annual rates were also computed by use of formula (1). In this latter instance, the denominator was set equal to the average of the 4 population bases that were used to obtain point estimates of quarterly rates. Estimates of the rates computed by both methods are shown in table 5.

TABLE 5

Comparison of the estimates of poliomyelitis rates as derived according to two computational methods: United States population under 20 years, 1957

TYPES OF POLIOMYELITIS	ANNUAL RATE (PER 1,000,000) COMPUTED BY USUAL METHODS	ANNUAL RATE (PER 1,000,000) COMPUTED BY RECOMMENDED METHODS
Paralytic and Nonparalytic		
No inoculations	83.1	90.5
1 or two inoculations	58.7	62.4
3 or more inoculations	31.9	28.9
Paralytic		
No inoculations	51.1	55.5
1 or two inoculations	21.5	22.8
3 or more inoculations	8.2	7.5

The rates for persons with 3 or more inoculations are higher when computed by formula (1), and the rates for persons with no inoculations and one or two inoculations are higher when computed by formula (2). The explanation for this is that in general formula (2) relates the date of onset of poliomyelitis cases more particularly to the population size exposed as of that date. In this example the exposure of the triply vaccinated group was more heavily concentrated in the quarters of the year during which the risks of getting poliomyelitis were greatest. It is noteworthy that the estimates of poliomyelitis rates for persons with no inoculations and for persons with one or more based on formula (1) are not contained within the bounds shown in table 3, and the estimates of the rates for persons with 3 or more inoculations are barely within the bounds.

The percent effectiveness of the vaccine based on both sets of estimates is shown below:

	USUAL METHODS	RECOMMENDED METHODS
Paralytic and Nonparalytic Cases		
1 or two inoculations	29.4%	31.0%
3 or more inoculations	61.6	68.0
Paralytic Cases		
1 or two inoculations	57.9	59.9
3 or more inoculations	83.9	86.4

Compared to rates computed by recommended methods, those computed by formula (1) tend to understate the vaccine's effectiveness. The estimates of vaccine effectiveness of three or more inoculations based on formula (1) are not contained within the bounds of the vaccine's effectiveness shown in table 4.

The possible misinterpretations resulting from the rates of the vaccine's effectiveness based on formula (1) are not necessarily confined to the present but may present problems in the future as well. Assuming that estimates of the vaccine's effectiveness will be computed in future years, they may raise questions in 1958 or 1959 or later as to why vaccine appeared to be less effective in 1957.

SUMMARY

Had poliomyelitis incidence rates of vaccinated persons and unvaccinated persons in the United States in 1957 been computed in the customary manner according to exposed-to-risk formulas, they would have been biased. The rates for triply vaccinated persons would have been overstated and those for unvaccinated persons and for persons who had been administered one or two inoculations would have been understated. The effectiveness of the vaccine, particularly when three doses had been administered, computed on the basis of these erroneous rates, would have been understated.

In general, the customary manner of computing rates according to exposed to risk formulas can give misleading results in situations in which incidence rates of the event show marked seasonality and the population at risk also undergoes substantial reduction or increase in size. This was the situation with regard to poliomyelitis incidence rates of vaccinated and unvaccinated persons in the United States in 1957. During that year, the population was participating heavily in the polio-

myelitis vaccination program, and the marked seasonality of the disease during the summer and autumn months was evident.

Since population counts of the vaccinated and unvaccinated population based on national household surveys were available only for a few dates during 1957, it was not feasible to compute unbiased cohort rates. In this paper, a method was developed for computing upper and lower bounds of the cohort rates which requires no more information than was available. The method was applied to poliomyelitis data for the population under 20 years of age and the results compared to those obtained by application of the conventional exposed-to-risk formulas. In view of the misleading results obtained by the exposed-to-risk formulas in this paper, the suggested procedure is being applied to poliomyelitis data by age, sex and geographic division available for the United States for 1957 to obtain measurements of the vaccine effectiveness.

The substantive findings regarding the vaccine's effectiveness are of interest in their own behalf. According to the results presented in this paper, three or more inoculations of Salk vaccine to the population under 20 years were between 83 and 89% effective against paralytic poliomyelitis. This result compares favorably with the measurement based on the 1954 field trial of poliomyelitis vaccine (Francis, *et al.*, 1957) which indicated that 3 inoculations of the vaccine to children 7, 8 and 9 years of age were about 80% effective against paralytic poliomyelitis.

APPENDIX

Let μ_t $(0 \leqq t \leqq 1)$ denote the force of mortality at time t from the beginning of the year. Then the cohort annual rate of mortality is

$$q = 1 - e^{-\int_0^1 \mu_t \, dt}.$$

Thus, we can compute q if we can determine

$$\int_0^1 \mu_t \, dt = -\log_e(1-q).$$

Let $N(t)$ denote the number in the population under study at time t, and let D denote the number of deaths during the year. Then

$$D = \int_0^1 N(t)\mu_t \, dt = \sum_{i=1}^{m} \int_{t_{i-1}}^{t_i} N(t)\mu_t \, dt,$$

where

$$t_0 = 0, \qquad t_m = 1, \qquad t_i > t_{i-1}.$$

If $N(t)$ is continuous and μ_t is nonnegative in each interval $t_{i-1} < t < t_i$,

$$D = \sum_{i=1}^{m} N(\xi_i) \int_{t_{i-1}}^{t_i} \mu_t \, dt = \sum_{i=1}^{m} D_i,$$

where

$$t_{i-1} < \xi_i < t_i.$$

Thus, $\int_{t_{i-1}}^{t_i} \mu_t \, dt$ can be estimated from $\int_{t_{i-1}}^{t} \mu_t \, dt = \frac{Di}{N(\xi_i)}$,

and $$-\log_e(1-q) = \sum_{i=1}^{m} \frac{Di}{N(\xi_i)}$$

or $$q = 1 - e^{-\sum_{i=1}^{m} \frac{Di}{N(\xi_i)}}$$

Since the fraction $q' = \sum_{i=1}^{m} \frac{Di}{N(\xi_i)} < 1$, the function $e^{-q'}$ is a convergent series

$$e^{-q'} = 1 - q' + \frac{(q')^2}{2!} - \frac{(q')^3}{3!} + \cdots.$$

Therefore, q may be rewritten as

$$q = q' - \frac{(q')^2}{2!} + \frac{(q')^3}{3!} - \cdots.$$

In applications for which q' is a small fraction, it serves as a reliable estimate of q.

LITERATURE CITED

BUREAU OF THE CENSUS 1958 Concepts and methods used in the current employment and unemployment statistics. Current Population Reports, Series P 23, No. 5.

FRANCIS, THOMAS, JR., *et al.* 1957 Evaluation of the 1954 Field Trial of Poliomyelitis Vaccine. Edwards Brothers, Inc., Ann Arbor, Michigan, pp. 272-276.

HILL, BRADFORD 1950 Principles of Medical Statistics. 5th edition, The Lancet Limited, London, p. 182.

SIRKEN, MONROE, AND BERTHOLD BRENNER 1959 Poliomyelitis vaccination participation differentials: United States, August 1957. Unpublished manuscript.

BOOK REVIEWS

The scope of physical anthropology and its place in academic studies. By J. S. Wiener and D. F. Roberts. 66 pp. Publ. for *Soc. for Study of Human Biol.* by Wenner-Gren Foundation for Anthropological Research, New York, N. Y., 1958. (Privately printed, not for sale. Now out of print).

Some years ago there was a radio character whose tag-line was, "That ain't the way I heerd it, Johnny!" In similar vein modern physical anthropology "ain't the way I learned it!", if this volume is any criterion. On Nov. 6, 1957, the Ciba Foundation sponsored a Symposium by British biologists especially interested in physical anthropology. The Wenner-Gren Foundation published the papers—*not* the accompanying discussion—and the Society for the Study of Human Biology was born of the Symposium. So much for background.

This is a double-barrelled approach: first, the scope of physical anthropology, secondly, how it fits into an academic program. The first can be answered by a generalization that all's grist that comes to and from the biological mill, i. e., there's nothing about Man's form and function that is not apropos to physical anthropology. The second is answered rather obliquely by Young: "I believe that the objective study of man by biological techniques such as an anthropologist can use provides as firm a foundation as any other for a liberal education."

To speak in a purely American lingo, you can't get to first base as a physical anthropologist today unless you are well grounded in genetics, physiology, biochemistry and microbiology. The traditional Measurer of Man—*ens corporis*—has given way to the measurement of tissues, cells, excretions, and energy-exchange systems. The whole has surrendered to its parts—nay, its fractions—with a vengeance! You no longer measure what you see: you experiment to determine if what you see is meaningful or not. No longer the what (the observed form), but the how (the mechanics) and the why (emergent or selective causation).

In physical anthropology—which has a formal 1859-1959 history—we have gone through what Le Gros Clark calls the "romantic" phase, wherein empiricism ruled, the biometric phase, testing the variability of human populations, to a more proper and more detailed study of the biology of Man, past and present, with experimentation a dominant

motif. In this third phase, the present, emphasis is upon human form and function in action, with respect to the external environment, as climatic factors, the work situation ("ergonomics," "occupational anthropology"), and so on.

Those of us who have been in the field over the years have seen the emergent trend, both in direction and in scope. I have long had the feeling that our field of human biology should be hand-maiden to the medical and dental specialities. This means that data derived from mass studies must be applicable to individual (clinical) instances. With this in mind I must confess that the volume under review worries me a bit. The direction is clear, but aim is not manifest. I am sure that this must have been realized and expressed via discussion at the Symposium, but the discussion is not given, and the papers, in their entirety are not integrative. In this sense Williams' "Biochemical Individuality" or Macy and Kelly's "Chemical Anthropology" did more thorough jobs. When all's said, however, the Symposium not only resulted in stimulating papers but in the establishment of a new Society. I am sure that synthesis will be only a matter of time.

WILTON MARION KROGMAN

Graduate School of Medicine
University of Pennsylvania

Methods for Research in Human Growth. By STANLEY M. GARN and ZVI SHAMIR. xi + 121 pp. Charles C. Thomas, Springfield, Ill. 1958. $4.75.

There is a first impression of surprise on connecting such a title with the size of this book. Can so vast a subject be dealt with in 121 pages? But in their introduction the authors make it clear that this is expressly a modest book and that each chapter could be expanded into a separate monograph. As they point out, there are many thousands of published investigations into this large field but very few describe methods—either general or more detailed. Is this book, then, a "do-it-yourself"? Not completely; what it does do, above all else, is to describe methods known to be acceptable and practical for the investigation of various aspects of physical growth, and to point out to prospective investigators the sort of thing they are getting into. This is a valuable service.

There are 21 chapters and the headings range from 'Skin' to 'Measurement of Strength and Muscle Function'; from 'Health Examination and Health Records' to 'Hair.' In reviewing the methods under each heading a very fair sample of bibliography is quoted, and the authors are never afraid to opinionate. This adds to the book's readability.

There are particularly good sections on introductory general considerations, radiation hazards, and dentition. There are some minor points which might cause differences of opinion and two are given as examples: First, in stressing the importance of reasonably exact timing of examinations in longitudinal studies, the suggested tolerances of earliness and lateness in days increase as the children become older, on the grounds that elapsed time since birth is increasing too. Irrespective of elapsed time since birth it is the *incremental* period which matters, and these "allowable" tolerances are very high.

Secondly, in a discussion of the assessment of skeletal maturity the authors show the main current methods to be either radiographic evaluation by comparative inspection with 'atlases,' or the award of scores in points to visible centers of ossification appearing on radiographs. They note that the commonly found deviations in order of appearance of these centers complicate and bias the 'points' systems. In fact, such systems must, and do, award points for shape changes as well as appearances, and they are designed to avoid biases from deviant sequences of ossification. These deviations probably complicate the atlas methods to a greater extent.

But such controversies merely whet the appetite and make the reader desirous of discussion and looking up the many references. Perhaps it should be remembered that the majority of growth research has emanated from the United States, and that readers in other countries may well be stimulated and helped by this publication.

The book becomes a little unbalanced by the fact that one fifth is devoted to statistical and graphical reporting methods. *Not* that the subject's extreme importance to investigators is minimized by the reviewer. On the contrary it is perhaps the most important facet to consider first. But this specialized and controversial subject perhaps does not merit such prominence in this particular publication. All are surely agreed to move warily in those areas with a long suffering biometrist always at one's elbow.

The publication is up to the usual excellent standard of the publisher.

It should have a permanent place in many departments which envisage entering the nettly field of human growth.

FRANK FALKNER

Child Development Unit
University of Louisville
Louisville, Kentucky

A Guide-Outline for the Study of Physical Growth in Children. By WILTON MARION KROGMAN. 99 pp. Philadelphia Center for Research in Child Growth, 1958. (Mimeographed; published in a limited edition and no longer available).

Anthropologically speaking, Wilton Marion Krogman has been a public benefactor for years, providing bibliographies, compendia and summary-accounts to the advantage of all. "Look it up in Krogman" is good advice, a time-saver, imperative in the smaller libraries, and still true for his latest *Guide-outline for the Study of Physical Growth.*

However, an outline that is more than a reference-list presents particular problems. There must be words between the citations, or they read like a directory of lawyers. The words must say more than "Jones and Jones wrote an article" (which is self-evident), they must guide, especially in a *Guide.*

Krogman seems to have trouble at times in choosing the exact words. Right at the beginning of the guide he describes biochemistry, physiology and psychology as "non-biological areas." Too many references are designated as "best" and in one admittedly difficult reference to articles by A. H. Washburn, he paints them as "a general overall more-or-less philosophical approach to conceptual thinking." The Fels Composite Sheet is incorrectly described as "rating scales," Sendroy's approach to surface-area estimates as "useful," a description like "definitive" quite overused in this booklet. Investigative, summary and discussion papers are lumped as "studies," leaving the user of the guide to discover which.

Lest the reader be misled, Krogman's guide-outline is useful, valuable and unmatched. The arrangement and divisions are reasonable and the formidable problem of sandwiching words between references reasonably well met. Nevertheless, one wishes that he would add criticism, analysis and interpretation to the bare bones of this outline. Since some of the

citations are unimpressive, some of the research poorly-conducted, but were properly included because of their uniqueness, it would be helpful to all readers if W. M. Krogman, who stands above reproach, would say so.

STANLEY M. GARN

Fels Research Institute,
Yellow Springs, Ohio

Behaviour & Physique: An Introduction to Practical and Applied Somatometry. By R. W. PARNELL. viii + 134 pp. Williams & Wilkins, Baltimore, 1958. $6.80.

The relationship of physique to temperament, and to disease, has fascinated man for centuries. It is found at the heart of the classical descriptions handed down to us in the great writings of clinicians of the past.

The work of W. H. Sheldon at Columbia University, with his first monograph in 1940, greatly stimulated research in this field. Doctor Parnell has reacted to this stimulus by working for several years on the subject at Oxford. This book is a record of his labors.

Doctor Parnell has used the Sheldonian principles of standardized photography and anthroposcopy, and added some direct measurements. His classification is based in the main on the assessment of the relative amounts of muscle, bone and fat in the body, and the linearity of the whole body frame. He has applied this 'somatometry' to samples of children and adults in reference to problems in the fields of education, mental health and genetics. It is here that we see the great need for really basic theory on this whole subject. The past-made criticisms of these and allied methods still hold: truly *independent* measures of fat, muscle, bone, mineral, water (a much neglected and vital component) and surface are first needed before this work can progress much further. Until we can truly assess total body composition (and let us emphasize that this is rarely a static entity) we cannot test the many hypotheses that are so impatiently waiting, nor the methods we might well be able to use in a reasonably simple way in the field. In addition it is a commonplace to say that our psychological colleagues and educators are probably having an even more difficult time assessing personality characteristics and abilities in truly objective ways. The reviewer never ceases to be

amazed at, nor to admire, the way skilled independent observers of 'somatotype' photographs agree in their assessments of some components of body build to a remarkably high degree. But, particularly in the light of recent critical discussions and energetic work in the areas of estimations of body composition, we have to then ask: what are they actually assessing?

This book makes it crystal clear that the subject is one of the most fascinating in Human Biology. The author points to the shortcomings of the techniques used and reinforces the stimulation provided by Sheldon. For this reason alone it is valuable indeed.

FRANK FALKNER

University of Louisville,
Louisville, Kentucky

BOOK NOTICES

TECHNIQUES OF POPULATION ANALYSIS. By George W. Barclay. xiii + 311 pp. John Wiley, New York, 1958. $4.75. An introduction to demographic methods, concerned with the basic concepts (rates, sources of error) and measurements of mortality, fertility, growth of population, migration, and allocation of manpower.

THE BIOLOGICAL WAY OF THOUGHT. By Morton Beckner. viii + 200 pp. Columbia University Press, New York, 1959. $6.00. "Examination of the parts of biological theory that are magnified in the organismic biologist's perspective."

THE BLOOD PRESSURE IN A POPULATION. By Johs. Bøe, Sigurd Humerfelt, and Frøystein Wedervang. 336 pp. A. S. John Griegs, Bergen, Norway. No price indicated. A well documented (66 pp. of tables) study on the relation between height and weight and blood pressure in almost the entire adult population of the city of Bergen.

PERCEPTION AND COMMUNICATION. By D. E. Broadbent. v + 338 pp. Pergamon Press, New York, 1958. $8.50. A general view of research on hearing from psychological standpoint, growing out of investigations carried out by the author and centered around the perception of speech.

BAILEY'S TEXTBOOK OF HISTOLOGY. Revised by Winfred M. Copenhaver and Dorothy D. Johnson. xiii + 633 pp. Williams and Wilkins Co., Baltimore, 1958. $11.00. The revision of this standard textbook (1st ed., 1904; 13th ed., 1953) takes into account the recent advances in the study of microscopic structure of tissues and cells (histochemistry, electron microscopy) and places increased emphasis on the physiological significance of structure.

PHYSIOLOGIE DES BEWUSSTEINS IN ENTWICKLUNGSGESCHICHTLICHER BETRACHTUNG. By U. Ebbecke. xi + 211 pp. Georg Thieme, Stuttgart, 1959. $6.40. A lecture on the physiology of consciousness, presented at the 1957 meeting of German physiologists, expanded into a book.

THE PHYSICAL FOUNDATION OF BIOLOGY: An Analytical Study. By W. M. Elsasser. x + 219 pp. Pergamon Press, New York, 1958. $4.75. This is a thoughtful theoretical physicist speaking. "The approach taken here was made possible by a threefold development: the theory of automata (often designated as computers), the theory of information (mainly developed in communication engineering), and the theory of microscopic measurement in the atomic and molecular domain" (p. ix).

RESEARCH WITH ISOTOPES IN HUMAN AND ANIMAL BIOLOGY AND MEDICINE. Edited by R. C. Extermann. xxi + 763 pp. Pergamon Press, New York, 1958. $22.50. Third volume of the series "Radioisotopes in Scientific Research" consisting of papers presented at the 1957 international conference held in Paris under the auspices of the UNESCO. Abstracts published in

English, French, Russian and Spanish. Emphasis, as would be natural, is on animal experimentation.

REPRODUCTION AND INFERTILITY. Edited by F. X. Gassner. R. Jensen, H. J. Hill, Assoc. Eds. vi + 267 pp. Pergamon Press, New York, 1959. $6.50. Proceedings of the third symposium devoted to the complex biological problems of reproduction, with two papers dealing specifically with man (maintenance of pregnancy with progestational compounds, classification of male hypogonadism).

RADIOGRAPHIC ATLAS OF SKELETAL DEVELOPMENT OF THE HAND AND WRIST. By William W. Greulich and S. Idell Pyle. xvi + 255 pp. Stanford University Press, 1959. $15.00. Second edition of the outstanding compendium of skeletal age standards (31 plates for males, 29 for females), with a section of the rationale and technique (pp. 1-60), and on "Maturity Indicators of Individual Bones and Epiphyses" (pp. 185-228).

INITIATION MATHÉMATICAL À LA PHYSIQUE MÉDICALE ET À LA BIOLOGIE. By Julien Guelfi. viii + 220 pp. Masson, Paris, 1958. 4,000 fr. A brief, well written vademecum covering all the relevant major facets of mathematics, including probability.

STATISTICS OF EXTREMES. By E. J. Gumbel. xx + 375 pp. Columbia University Press, New York, 1958. $15.00. In biology problems for which statistics of extremes is relevant do not abound. Yet, they are there (oldest age in population statistics, e. g.). Gumbel's volume is a unique methological guide to their treatment.

BIOLOGICAL LABORATORY DATA. By L. J. Hale. x + 132 pp. John Wiley, New York, 1958, $2.75. Selected information on mathematical and statistical formulae, weights and measures, and other matters (physics, chemistry, histological techniques) of interest to the biologist.

THE FAMILY AND POPULATION CONTROL: A PUERTO RICAN EXPERIMENT IN SOCIAL CHANGE. By Reuben Hill, J. Mayone Stycos, and Kurt W. Back. xi + 481 pp. University of North Carolina Press, Chapel Hill, 1959. $8.00. A study of population control viewed as a phenomenon of family planning, focused on the paradox of widespread acceptance of the ideal of a small family size and the absence of decline in fertility, ending with recommendations for government program of action.

RUSSIAN-ENGLISH MEDICAL DICTIONARY. By Stanley Jablonski. Edited by Ben. S. Levine. xi + 423 pp. Academic Press, New York, 1958. $11.00. The purpose of the volume is "to fill a long-standing need for a specialized tool designed for the English translation of Russian medical literature." Well filled! Published with material assistance from the Russian Scientific Translation Program, U. S. Public Health Service.

PRATIQUE DU LABORATOIRE. Edited by Ch. Jaulmes, A. Jude, J. Quérangal des Essarts. 872 pp. Masson, Paris, 1958. 7.600 fr. A compendium of medical laboratory procedures. For the readers of this journal the section on blood groups (p. 543 f.) may be especially relevant.

THE NEGRO PERSONALITY. By Bertram P. Karon. vii + 184 pp. Springer Publishing Co., New York, 1958. $4.50. "Combining the statistical control of repeated samples with the depth of a projective technique, Dr. Karon illuminates the world which the white American has created for the colored American." (from S. S. Tomkins' forward).

PHYSIOLOGY OF MUSCULAR ACTIVITY. By Peter V. Karpovich. xvii + 368 pp. W. B. Saunders Co., Philadelphia, 1959. $5.50. Fifth edition of the old standby, originally written by E. C. Schneider, with a chapter on the relation of body type and posture to physical fitness.

NUTRITION AND ATHEROSCLEROSIS. By Louis N. Katz, Jeremiah Stamler, and Ruth Pick. 146 pp. Lea and Febiger, Philadelphia, 1958. No price indicated. A comprehensive review (close to 800 references) and appraisal of the rapidly growing field of research on the significance of nutrition in the development of atherosclerosis.

THE MEDICAL WORLD OF THE 18TH CENTURY. By Lester P. King. xvii + 346 pp. University of Chicago Press, Chicago, 1958. $5.75. "A series of loosely related essays dealing with phases of the medical scene that are generally neglected in the formal histories" (Ilza Veith, in the Forword).

SYLLABUS IN ROENTGENOGRAPHIC CEPHALOMETRY. By Wilton Marion Krogman and Viken Sassouni, 366 pp. Philadelphia Center for Research in Child Growth, Philadelphia, 1957. No price indicated. An inventory of the literature (22 pp. of references), evaluation of technic and X-ray film interpretation (landmarks, measurements) plus appraisal of relation to collateral sciences.

MENTAL SUBNORMALITY. By Richard L. Masland, Seymour B. Sarason, Thomas Gladwin. 442 pp. Basic Books, New York, 1958. $6.75. A survey of research on biological, psychological, and cultural factors, sponsored by the National Association for Retarded Children.

CHEMICAL BASIS OF DEVELOPMENT. Edited by William D. McElroy and Bentley Glass. xi + 934 pp. Johns Hopkins Press, Baltimore, 1958. $15.00. A symposium held at Johns Hopkins University in honor of Professor B. H. Willier, distinguished teacher and investigator in animal development, a field encompassing a wide range of problems and requiring participation of various disciplines, including embryology, biochemistry, and genetics.

LOOKING AT CHROMOSOMES. By John McLeish and Brian Snoad. vii + 87 pp. St. Martin's Press, New York, 1958. $3.75. By text, drawings and—most importantly—a series of photographs the authors portray the behavior of chromosomes in plant cells, emphasizing that the mechanisms underlying heredity are fundamentally similar in plants and animals.

MODERN SCIENCE AND THE HUMAN FERTILITY PROBLEM. By Richard L. Meier. xiii + 263 pp. John Wiley, New York, 1959. $5.95. Centered around the potential breakthrough in fertility control by means of oral contraceptives and the analysis of social consequences of scientific discovery.

SOCIOLOGY TODAY. Edited by Robert K. Merton, Leonard Broom, and Leonard S. Cottrell, Jr. xxxiv + 623 pp. Basic Books, New York. $7.50. The three editors and 27 contributors set out "to sort out and critically examine problems for investigation that developments in the major branches of sociology have thrust into prominence."

SELECTED STUDIES OF MIGRATION SINCE WORLD WAR II. 244 pp. Milbank Memorial Fund, New York, 1958. $1.00. Migration is considered both within the international context and in the U. S. setting, including theoretical (models in migration) as well as economic aspects.

BIOLOGY OF HAIR GROWTH. Edited by William Montagna and Richard A. Ellis. xvii + 520 pp. Academic Press, New York, 1958. $15.00. Spanning the life cycle (Ch. 1 Embryology of hair; Ch. 20 Aging of the human male scalp), combines the morphological and functional methods and viewpoints, including histochemistry and electron microscopy. Includes "Age, sex and genetic factors in the regulation of hair growth in men" (Ch. 16).

RECOMMENDED DIETARY ALLOWANCES, 36 pp. Publication 589, National Academy of Sciences—National Research Council, Washington, D. C., 1959. $1.00. A 1958 revision of the standard guide concerning nutrient allowances "for the maintenance of good nutrition in healthy persons in the U. S. A."

FEDERAL FUNDS FOR SCIENCE. VII. The Federal Research and Development Budget Fiscal Years 1957, 1958, and 1959. National Science Foundation, iii + 78 pp. The U. S. Government Printing Office, Washington, D. C. $0.45. Analysis of the volume of funds provided for research and development through the Federal budget.

FUNDAMENTALS OF ECOLOGY. By Eugene P. Odum. xvii + 546 pp. W. B. Saunders Co., Philadelphia, 1959. No price indicated. Two chapters are devoted specifically to applications of human ecology but other sections, e. g., the treatment of radiation (Ch. 14), are also relevant.

HORMONE UND PSYCHE: DIE ENDOKRINOLOGIE DES ALTERNDEN MENSCHEN. (Hormones and Psyche: The Endocrinology of the Aging Man.) Edited by H. Nowakowski. vii + 355 pp. Springer-Verlag, Berlin, 1958. No price indicated. Symposium of the German Society for Endocrinology. Clinically oriented.

THE VERTEBRATE STORY. By Alfred Sherwood Romer. vii + 437 pp. University of Chicago Press, Chicago, 1959. $7.00. A well told account of the structure, function and ways of life of the backboned animals, with the evolutionary story as the leading theme. The last three chapters deal with primates, including man.

DIFFERENTIAL FERTILITY IN BRAZIL. By J. V. D. Saunders. x + 90 pp. University of Florida Press, Gainesville, Fla., 1958. $3.50. Analysis of the rates at which various residential, racial, regional and other (occupational, religious, socioeconomic) groups reproduce in a nation with a tremendous development potential.

AGGRESSION. By John Paul Scott. xi + 149 pp. University of Chicago Press, Chicago, 1958. $3.75. Aimed at the causes of aggressive behavior in the animal kingdom, the volume clarifies the implications for human behavior.

LE PLACENTA HUMAIN: ASPECTS MORPHOLOGIQUES ET FONCTIONNELS. By Prof. Jean Snoeck. 718 pp. Masson, Paris, 1958. 7.500 fr. An outstanding monograph on the morphology, biochemistry and physiology of human placenta by the research team of the Clinic of Gynecology and Obstetrics, Free University of Brussels.

SONDERAUSSCHUSS RADIOAKTIVITÄT BUNDESREPUBLIK DEUTSCHLANDS. 68 pp. Georg Thieme, Stuttgart, 1958. $1.10. The first report of the West German Committee on Radioactivity. Of special relevance is Ch. 3 dealing with the appraisal of the radiation load on the population.

CLIMATOLOGY: REVIEWS OF RESEARCH. UNESCO. 190 pp. UNESCO Publication Center, New York, 1958 paper. $5.00. Of special interest is D. H. K. Lee's chapter on the microclimates (climatic circumstances affecting an individual at a given moment, "proprioclimates") of man and domestic animals.

HUMAN AND ANIMAL ECOLOGY: REVIEWS OF RESEARCH. 244 pp. UNESCO Publication Center, New York, 1957. No price indicated. Two out of the seven papers deal with the effects of environment in arid regions on man (human communities, the biology of man).

GENERAL SYSTEMS. Vol. 3. Edited by Ludwig von Bertalanffy and Anatol Rapoport. Society for General Systems Research, Ann Arbor, Mich., 1958. No price indicated. The third yearbook of the Society of General Systems. The bulk of the volume is devoted to biology and, in particular, to evolution and to population dynamics.

WENNER-GREN FOUNDATION FOR ANTHROPOLOGICAL RESEARCH, INC. Report on the Foundation's Activities for the Year Ended January 31, 1958. 90 pp. Report of activities and publications resulting from research supported by the Foundation. Substantial amount of financial help was allocated to physical anthropology.

AVIATION MEDICINE. Edited by Clayton S. White, W. Randolph Lovelace, II, and Frederic G. Hirsch. vii + 305 pp. Pergamon Press, New York, 1958. $9.80. Assessment of recent advances in methods dealing with selected topics, including spirometry, temperature measuring techniques, and uses of high-speed motion-picture photography.

THIRST: PHYSIOLOGY OF THE URGE TO DRINK AND PROBLEMS OF WATER LACK. By A. V. Wolf. x + 526 pp. Charles C. Thomas, Springfield, Ill., 1958. $12.50. A veritable storehouse of physiological and medical knowledge about water intake, including consequences of sea water drinking. In the second part (p. 371-422) the laboratory, clinical and field studies are supplemented by classical accounts of the effects of "real-life" water deprivation.

NEUROLOGICAL BASIS OF BEHAVIOR. Edited by G. E. W. Wolstenholme and Cecilia M. O'Connor for the Ciba Foundation. xii + 400 pp. Little, Brown, and Co., Boston, 1958. $9.00. Proceedings of an outstanding symposium, multidisciplinary in nature.

THE MEASUREMENT OF COLOR. By W. D. Wright. ix + 263 p.. The Macmillan Company, New York, 1958. $10.75. Competent presentation of the principles, methods, and applications of the trichromatic system of color measurements.

THE BIOLOGY OF AGING. Edited by W. G. Yapp and G. H. Bourne. xiv + 128 pp. The Institute of Biology, London, 1957. $3.50. At least one half of the volume is likely to be of direct interest to readers of *H. B.* (demographic aspects, longevity, working capacity, nutrition).

JOSEF BROŽEK

Lehigh University